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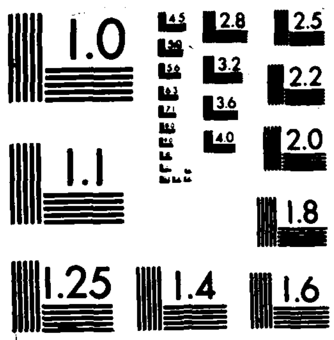

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AD-A174 651

USE OF BAR CODING IN THE PERFORMANCE OF PHYSICAL INVENTORIES ON UNITED STATES AIR FORCE MEDICAL EQUIPMENT MANAGEMENT OFFICE (MEMO) CONTROLLED PROPERTY

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirement for the Degree of Master of Science in Logistics Management

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September 1986

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Terence W. Beckwith

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Abstract

This research examined the times and techniques necessary for individuals responsible for property accountability within USAF medical facilities to conduct physical inventories on medical and nonmedical equipment. Because this property accountability normally is an additional duty and their primary mission is that of patient care, the amount of time required to conduct these inventories should not be excessive. This is especially true when there are more advanced techniques available that would improve the efficiency and decrease the time required to conduct these inventories. The examination included a review of how the present physical inventories are being accomplished and the advanced techniques available that would expedite this process. Trial physical inventories were performed on two accounts using both the present physical inventory method and the technique of bar coding. In addition, a simulation model for each method was developed using the results from the trial inventories. The results of the trial inventories and the output from the simulation models were analyzed and compared. The conclusions reached as a result of the comparison are that the present method of conducting physical inventories is inefficient and the use of bar coding would dramatically decrease physical inventory times and improve efficiency.

USE OF BAR CODING IN THE PERFORMANCE OF PHYSICAL INVENTORIES ON UNITED STATES AIR FORCE MEDICAL EQUIPMENT MANANGEMENT OFFICE (MEMO) CONTROLLED PROPERTY

I. Introduction

General Issue

Annually, physical inventories of Medical Equipment Management Office (MEMO) controlled property are accomplished in United States Air Force medical facilities. These physical inventories may be accomplished more often if determined necessary by the medical facility commander (12:p18-13). In my 15 years of logistics experience in military medical facilities, it has been my observation that these physical inventories are normally accomplished by the property custodian.

A property custodian is any individual designated by the organization commander or chief of a staff agency to have custodial responsibility for property in the property custodians possession. Air Force Regulation (AFR) 20-14 states:

> Personnel having custodial responsibility may incur pecuniary liability for the loss, destruction, or damage to property caused by willful misconduct, deliberate unauthorized use, or negligence in the use, care, custody, or safeguard of the property from causes other than fair wear and tear (11:2).

In medical facilities a majority of the property custodians have this responsibility as an additional duty. They are not specifically trained for it. The primary duties of the individuals appointed as property custodians take on the full range of hospital duties; from being a pharmacy technician who fills prescriptions for patients to a medical technician who administers the prescription to the patients. They could be a cook in food service or a laboratory technician who draws blood for testing.

One major problem with being appointed as a property custodian is the tremendous administrative workload associated with the appointment. AFR 20-14 states that:

> Custodians of government property are charged with preparing and forwarding equipment requests, signing custody receipts or listings for property charged in their area of responsibility, complying with all directives and instructions relating to property in their charge, promptly reporting any losses or irregularities, and initiating actions to reconcile or correct property records (11:2).

Besides this being an administrative burden it distracts medical facility property custodians from their primary mission, patient care.

An example is a Non-Commissioned Officer (NCO) of a large medical ward who has been assigned the additional duty as property custodian in conjunction with the primary duty of supervising all medical technicians assigned to the ward. It is the ward supervisor's responsibility to insure all patients receive proper care. To do this, the supervisor must insure all medical technicians are properly trained in patient care and are applying these techniques appropriately. If the supervisor is occupied performing the duties associated with being a property custodian and is unable to schedule training sessions or perform on-the-job training, the assignment as property custodian distracts the supervisor from performing the primary duty of patient care. This problem is evident in all medical facilities and is especially noticeable in the larger facilities.

Problem Statement

In large medical facilities, the value of equipment inventories can total tens of millions of dollars and it is not unusual for the MEMO to complete one annual physical inventory and immediately initiate the next year's. Property custodians frequently change, forcing property accounts to be inventoried more than twice a year. In addition, numerous medical assets are highly mobile and difficult to track. This requires a tremendous expenditure of manpower and time each year in tracking equipment. Due to the workload from patient care and other health related activities of the medical facility, such as environmental health or outpatient records, time used tracking equipment and performing physical inventories distracts from patient care and the primary responsibilities of all personnel associated with the medical facility.

Research Questions

The situation described is not unusual or unique to just a single medical facility. Because it does affect nearly all medical facilities in the USAF, certain questions which require research can be asked which, when answered, will help to alleviate the condition described.

1. With these inventories being mandatory, is the present method an efficient way to accomplish them?

2. If not, are there more efficient methods in use now?

3. What method or methods are the civilian health industry utilizing?

4. Is the civilian health industry developing more efficient methods for physical inventories?

5. Are similar methods in use in other industries within the Air Force, Department of Defense or other Federal agencies?

6. If so, are these methods adaptable to the Air Force medical field?

7. If they are, can they be applied to medical logistics and will they increase efficiency?

These questions form the basis of the research and are addressed in more detail in the Methodology section.

Scope

Source Data Automation (SDA) is a term used to describe various means of collecting data about an event in computer readable form at the point and time of the event's occurrence. SDA techniques are among several advanced data entry methods currently being used in government and private industrial facilities, as well as in such service sector activities as hospitals, schools, and retail stores (28:1). One SDA technique is the optical scanning of machine readable symbols. It is an information processing technology that converts data into an acceptable media for computer input. One specific type of machine readable symbol is the bar code (17:3). Since the Department of Defense and civilian sector are utilizing bar codes increasingly, the aspect of SDA dealing with it is the area being explored in the research.

Most bar codes are horizontal codes consisting of alternating vertical dark bars and light spaces. Some various types of bar codes are Bullseye, Binary Coded Decimal (BCD), Decimal, Distribution Code (DC), Digital, Universal Product Code (UPC), Codabar, Interleaved "Two-of-Five", Bi-Level, Periodic Binary, Geometric, "Two-of-Five", and "Three-of-Nine" (17:4,5). Since the Department of Defense (DOD) has approved the "Three-of-Nine" code as the standard symbology, its application will be the only bar code discussed in detail and considered in this research (17:16).

Objectives

The purpose of this research is to explore the investigative questions stated above and to actually perform a trial run using and comparing the present method of performing a physical inventory against the more advanced use of bar codes. The overall objective of this research is to verify that bar coding of medical and non-medical equipment in medical facilities will result in greater inventory control, reduce the administrative burden, increase accuracy, improve efficiency and decrease the time required to perform physical inventories.

Assumptions

In order to perform this research it is necessary to make some assumptions to establish a framework and baseline to guide the research process. The following form that basis:

1. Present regulations governing physical inventory procedures will not change.

2. Bar coding is an accepted and proven technique to improve efficiency of inventory control, and consequently no attempt will be made to justify it again.

3. The DOD Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) program has accepted the

"Three-of-Nine" code as a standard and for the intent of this research it is the bar code symbology to be used.

4. The USAF Medical Center, Wright-Patterson AFB Ohio, has similar equipment accounts in comparison to other USAF medical facilities.

5. The label containing bar code information will be affixed properly so it is in visible range to be scanned.

The assumptions made on present physical inventory methods, governing regulations, bar code technology, account structure and labels, govern the environment of the research. Even with these assumptions certain limitations were encountered and they are presented next.

Limitations

1. A complete bar code system for use in this research was not attainable. A work-around was developed to compensate for this situation. However, accessibility to an Air Force Wright Aeronautical Laboratories (AFWAL) Logistics Material Control Activity (LMCA) bar code reader was also restricted. This limitation impacted the size and number of accounts selected to perform trial physical inventories at the Wright-Patterson AFB Medical Center.

2. Another restriction that impacted the size and number of property accounts selected was the primary mission of the property custodians being patient care. The amount of time a property custodian could provide to assist in the trial physical inventories was a premium. For this reason

only property custodians who showed a willingness to participate and who had property accounts having more than 30 items were selected.

II. Methodology

Development of Procedures

To properly evaluate the present and any advanced method of performing physical inventory, several key steps need action. These steps are incorporated into four milestones.

Milestone I - Literature Review

In this milestone, research questions 1 through 5 were evaluated and preliminary results obtained. The following steps were performed to accomplish this:

1. A review of the present method of performing equipment physical inventories and the governing regulations was accomplished.

2. A search and review of literature pertaining to advanced techniques and technologies was performed.

3. From the review, the scope of technologies was narrowed to the most frequently used and accepted.

4. The technology examined was Automatic Identification with a more detailed literature search and review on bar coding.

5. Numerous vendors were contacted through the periodical "Modern Materials Handling."

6. Department of Defense (DOD) agencies responsible for the Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) program were contacted.

7. Local vendors were contacted and points of contacts of local DOD and USAF users were obtained.

8. The local users of bar coding were then contacted to obtain information on their systems and procedures.

<u>Milestone II - Set-up, Procedures Used and Performance of the Physical Inventories</u>

In this milestone more definitive answers to research questions 1, 6 and 7 were sought. The procedures used to obtain the results for Milestone III were the following:

1. To compare the two different physical inventory techniques it was necessary to inventory the same property accounts using both methods. The accounts selected contained a representative sample of the various categories of equipment. Two accounts having a minimum of thirty items and meeting this criteria were selected.

2. These accounts were then inventoried using the present physical inventory method. This served a dual purpose. First, the length of time it took to perform and annotate the custodial receipt locator listing was monitored and recorded. Second, it provided the opportunity to tag the items inventoried with a bar code tag that would be used in the later inventory using bar code reader/scanners.

3. Once both property accounts had been inventoried, equipment tagged, and results recorded, the

next step was to perform the inventory again using the bar code reader/scanners.

4. Using the bar code reader/scanner, the same procedures followed in the previous inventory were again accomplished.

5. The length of time it took to scan each label and complete the inventory was recorded.

6. To supplement and support the times and findings of the bar code inventory, a representative from the 4950th Logistics Materiel Control Activity (LMCA) and Air Force Wright Aeronautics Laboratory (AFWAL) LMCA were accompanied while performing physical inventories. These activities are presently using bar coding for inventory control under the guidelines of the Equipment Management Accounting System. As these individuals performed their inventories, times, procedures used and any observations were recorded.

Milestone III - Results and Analysis of Methods

This milestone is divided into two parts. The first part contains a table that summarizes the times recorded, and observations made on each inventory. The second part contains an analysis of the two different physical inventory methods. The findings from this milestone will be used in Milestone IV. There is no attempt in this milestone to justify either method as this is covered in the conclusion.

Milestone IV - Development of Simulation Models

In this milestone, research questions 1, 6 and 7 were evaluated from a conceptual standpoint. From the information obtained during Milestone I and the results from Milestone III, simulation models for the present method of physical inventory, and for the use of bar coding techniques to accomplish this same task, were constructed. The following procedures were used in the model development:

1. From the review of the present method of physical inventory, a basic flow graph of how the property custodian conducts the inventory was devised.

2. Fifty-Two current custodial receipt locator listings were obtained from the Medical Equipment Management Office of the Medical Center at Wright-Patterson AFB, Ohio.

3. Each individual listing was then evaluated and the equipment on each listing categorized as being stock number controlled, index number controlled, serial number controlled, both index and serial number controlled or all of the above categories.

4. A spreadsheet was then developed so the percentage in each category could be ascertained. This was necessary because of the difference in the amount of time required to inventory each category of equipment under the present method of doing the physical inventory.

5. Based on past personal experience in performing physical inventories and on contacts with five

property custodians, estimates about the amount of time required to inventory each category of equipment were developed.

6. From the information gathered the flow graph devised was then coded in SLAM computer terminology.

7. This coded program was then entered into the Classroom Support Computer (CSC) and the program run.

8. Results were obtained and analyzed. These results were then compared against the recorded times from the physical inventories that were accomplished.

9. Based on the difference between the model and actual times, the model was adjusted appropriately.

10. From the literature search on bar coding, a flow graph of how the property custodian would conduct a physical inventory using this technique was developed.

11. Based on percentage improvements in efficiency stated in the literature search and through contact with present bar code users, times were derived to be used in the coding of this model.

12. This coded program was then entered in the CSC and results obtained.

13. Results from the model and times recorded from the bar code inventories were then compared and the final model adjusted appropriately.

14. The final models were then run again and an analysis of the two models was accomplished.

III. Milestone I - Literature Review

Present Method of Physical Inventory

Separate property accounting records are maintained for each item in inventory having a different stock number and item description (12:p3-1). A stock number is composed of up to 15 numbers and letters. It is used to uniquely identify each item of supply or equipment. Stock numbers fall into two major groups: stocklisted and nonstocklisted items. Stocklisted items are managed in the Federal Supply system and their stock numbers consist of 13 numbers with two additional positions which are normally left blank. These stocklisted items are also referred to as National Stock Numbers (NSNs). Nonstocklisted items are not managed by the Federal Supply system and are obtained from commercial vendors. These nonstocklisted items are also referred to as local purchase items. Local purchase (LP) stock numbers contain up to 15 positions and consist of both numbers and letters (10:9-2 to 9-3).

In addition to the stock number accounting described above, equipment which requires extensive maintenance is assigned an index number, which then becomes synonymous with the manufacturers serial number (10:p67-2). There is no requirement in the medical regulations governing the tagging or marking of assets so as to display the stock number and description of the item. However, for those items which require extensive maintenance, the index number is affixed. Generally, the serial number is engraved, embedded or attached to the equipment by the manufacturer. Each piece of accountable equipment used in a particular section of a medical facility is listed on a custodial receipt locator listing for that section. This listing is in stock number sequence and contains the description and/or index number and/or serial number, if appropriate.

When a property custodian must inventory the account, contact is made with MEMO to obtain a current custody receipt/locator listing (10:p72-4.1). In performing the physical inventory the property custodian takes this listing and locates the items listed. This usually means going from room to room, identifying each piece of equipment. If the item is indexed and/or serial number controlled the property custodian must insure these numbers match in conjunction with the stock number. As the physical inventory is being accomplished the property custodian posts the listing with the location of each item. Any discrepancies such as overages or shortages must be immediately rectified. The physical inventory is not normally closed out or certified as complete until all discrepancies are resolved (12:13c).

If a property custodian is familiar with the account and all items can be accounted for, the inventory is a relatively simple procedure and can be accomplished in a reasonable time frame. This time frame can range from an hour, to a day or even a week depending on the size of the account. However, numerous equipment items in a medical facility are highly mobile and are moved about to enhance patient care. To provide an example, when a backup respirator or defibrillator located on a ward is needed in the emergency room there is no delay in its transfer because of the life saving nature of this type of equipment. These items may only be borrowed for an immediate need with the intent they be promptly returned. However, it is not unusual for the item to move with the patient to another area outside the emergency room once the emergency has terminated. If someone is not tracking the equipment items, they could become misplaced. Although these items are usually located later, it causes delays in the inventory process.

This present method of performing physical inventories on equipment is extremely time consuming. Automatic Identification Technologies offer advanced methods to perform the physical inventory procedure. In the next section the different Automatic Identification Technologies are briefly discussed.

Automatic Identification Technologies

Automatic identification technologies fall into two categories; image and non-image based (5:82-83). The following looks at both categories and describes each of the technologies which fall under them.

Imaged-Based

Bar Codes. Data is encoded in alternating light an dark bars of varying thickness and a considerable amount of data can be encoded in a little space. This encoded data is read by a scanner or light pen. It is a low cost system with a high reading accuracy. The error rate is approximately one in three million reads (5:82). Bar Code is the most prominent type of automatic identification technique in manufacturing because of its reliability, storage capacity, ease of use, and low cost (5:83). Newer technologies and equipment are allowing enhanced use of bar codes. New equipment such as multiplexers and sophisticated data collection systems significantly enhance the integration of bar code information with other facility operations (4:74). Smart labels are now available which allow users to collect bar code and environmental data in a single scan. In fact, one smart label developed will indicate exposure to heat to aid in predicting food shelf life. The longer the specialty plastic in the label is exposed to temperatures above a certain level, the darker the label becomes. There have also been recent developments of integrated automatic identification systems that read bar codes as well as OCR and magnetic stripe (4:74-75). Another new technology that will extend the use of bar codes is laser etching. Laser etching engraves the bar code into an item where heat or other factors would destroy a paper tag (4:73).

Optical Character Recognition (OCR). These are printed alphanumeric codes that can be used alone or with bar codes. This code is human readable, low cost, has variable reading accuracy, and does not require a sophisticated computer system to be decoded (5:82). The advent of laser etching promises to extend the use of OCR (4:73). Bar codes printed with insufficient contrast between dark and light bars often can be read by machine vision as can black-on-black codes. OCR characters can be read at a distance. This greatly enhances its suitability for manufacturing processes (5:82).

Vision Systems. A video system reads many automatic identification codes and identifies parts. It can be tied to a main computer and has a high cost. A vision system reads at slow to moderate speeds and requires a line of sight for it to read. This system does have the advantage of being able to distinguish shapes (5:82). In the past four years, object recognition speed has increased from two characters per second to twenty and by 1987 it is expected to be between 40 to 60 characters per second. The size and resolution quality of video cameras and processors has drastically improved. A 7 x 4 x 6 inch camera is now 3 x .75 x 2.5 inches or the size of a cigarette pack. The resolution is up from 300 to 500 lines per inch and the overall price of the system has fallen from $50,000 to $28,000. Some processors can handle up to 8 cameras, so the price per camera station cost has dropped from $6,000 to $4,500 (4:76).

Non-Imaged Based

Radio Frequency (RF) and Surface Acoustic Wave (SAW). Both techniques encode data on a chip encased in a tag. When the chips are in range of a special antenna they are decoded by a reader. Unlike the SAW chips, the RF chips can be programmed and carry more data. Both type chips are very expensive but a major advantage is that their reliability is not affected by dirt or line of sight. What this means is that they can function where bar codes cannot. The two techniques fit processes that may coat the tag with dirt or grease, and ones that require the tab be out of line of sight of the reader or as much as six feet distant. They have read/write capabilities which allow data to be added, deleted or changed on the tag. The read/write tags can control equipment moving on a production line (5:83-84). The size of the chip is being decreasing from 4 x 8 x 1 inch to 2 x 2 x 5/8 inch which makes hardware for RF and SAW technologies more versatile. The cost for the readers for these technologies has fallen from $2,500 to $500 a reader (4:76).

Magnetic Stripe. A coded message is programmed onto a magnetic film attached to a special card and non-contact readers decode data. This technique has a high data density, is reprogrammable, and is unaffected by dirt or oil. As stated earlier it can be integrated with bar code and OCR (5:83).

Voice Recognition. This is a computer-based system that translates operators spoken words into computer data without special codes. This completely frees the worker to handle products and enter data into the computer at the same time. Besides being expensive there are two major problems with this system. This system requires extensive training of the operators to learn how to talk to the machine. In addition the machine has a limited vocabulary of about 300 words (5:82-84).

Although all the Automated Identification Technologies have excellent potential for application, the use of bar code techniques is one that is addressed in this research. Bar codes predominate in manufacturing today. They offer high reliability, ease of use, ability to store considerable data in a small space, and relatively low cost (5:83). Scanning a bar code is faster than manually recording information or keying data into a terminal (1). Bar coding offers the health-care industry the opportunity to decrease time personnel spend in performing inventories and increase the accuracy of data entry into automated systems (23:2723). In fact, any application where faster and more accurate data entry into an automated system will result in increased operational effectiveness is candidate for the use of bar codes (17:11).

Background of Bar Code

The first patent for bar code symbology was filed in 1949. One of the first major applications of bar coding was in 1967 by the railroad industry. The Association of American Railroads adopted an automatic car identification label to aid in monitoring the movement and current locations of its freight cars (29:20). In the spring of 1971, General Motors installed its first totally automatic bar-code-based production-monitoring system to count transmissions as they came off the assembly line (23:2727). The Grocery industry adopted the Uniform Product Coding as its industry standard in April of 1973 (23:2727). Supermarkets and their suppliers use this code for item identification and bar code readers for in-store automatic checkout and inventory control.

Soon thereafter, bar codes began appearing on material components, finished goods, shipping containers, warehouse bins, bills of lading and other distribution documentation (17:1). Numerous Federal agencies adopted and presently use bar codes or some form of optical readable characters. The Department of Agriculture uses bar coding for inventory control of all property items with a value of $200 or more. The Census Bureau uses it for inventory control of mechanical office equipment. The Department of Energy runs a perpetual inventory and uses bar codes. With the help of bar codes they can control by location and accountable personnel, some 43,000 items of highly mobile nuclear testing equipment (17:12-13). With numerous civilian and federal agencies successfully using bar codes the Department of Defense also decided to look into the possibility of its use.

Bar Coding in the Department of Defense

In 1976, a Joint Steering Group for Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) was chartered by the Office of the Assistant Secretary of Defense to establish a standard machine-readable symbology to be marked by commercial vendors and Department of Defense (DOD) activities (17:16). On 1 September 1981, the Office of the Secretary of Defense (OSD) Joint-Steering Group published its final report on the LOGMARS study, which documented over 5 years of use of bar code symbology. The recommendations of this report were approved by OSD and the OSD adopted the 3-of-9 bar code as the Department of Defense (DOD) standard (13;17:16).

Some characteristics of the 3-of-9 bar code are that it is of variable-length, bidirectional, discrete, self-checking, and alphanumeric. Its data character set contains 43 characters: zero through nine, A through Z, dollar sign, slash, plus, period, dash, percent, and space. Each character also contains nine elements: five bars and four intervening spaces. Further, each character contains some combination of two wide bars and three narrow bars separated by some other combination of one wide space and three narrow spaces. The narrow bars and spaces represent a binary zero and the wide bars and spaces represent a binary one. Spaces between characters are not significant. An asterisk character (*) is used exclusively for both the start and stop codes and allows for bidirectional scanning (17:6).

Uses of the bar codes have been tested by DOD agencies at the Defense Depot in Ogden for inventory and location survey of three thousand storage locations and at the Concord Naval Weapons Station for inventory of ammunition (17:18-19). In the first case there was a 6% productivity improvement in data collection as well as decreased processing time for data reconciliation with improved data accuracy (17:18). In the second case, it was determined that on the average, physical inventory could be conducted using bar code scanning at 80% less than the cost of conducting a conventional inventory of the same material

(17:18). As of 1982, DOD estimated savings using bar code instead of conventional methods to be $113.9 million (17:19).

Health Industry Bar Code Use

In June 1983 the American Hospital Association (AHA) and the Health Industry Distributors Association (HIDA) sponsored a meeting to develop ideas for achieving bar code standardization within health care. A twelve person industry wide task force was composed to develop bar code standards and specifications. In late 1983 the task force presented their findings at a meeting and the Health Industry Bar Code Council (HIBCC) was formed. On March 15, 1984 the Health Industry Bar Code Standard was published and is referred to as the HIBC Supplier Labeling Standard. On September 5, 1985, the HIBC Provider Applications Standard was approved by the HIBCC (23:2727).

The HIBC Standard is based on the Code 39 or 3-of-9 bar code symbology which was explained earlier. The use of this bar code in health care is voluntary so every hospital is different in the way it uses bar codes. Some applications of bar codes in health care being used by different hospitals include the coding of blood containers, roentgenograms, medical records, exchange carts from materials management, order entry on nursing units, patient wrist bands and capital equipment (23:2728). Even though hospitals use bar codes in different ways, the components of all bar code system are fairly standard.

Bar Code System Components

The American National Standard Institute defines a bar code symbol as:

> A graphic (printed or photographically reproduced) bar code composed of parallel bars and spaces of various widths intended for use in the detection and automatic processing of item identities or other intelligence by electro-optical means. (23:2723)

A bar code system is normally composed of the bar code symbol and associated processing equipment. The associated processing equipment consists of the bar code printer or reproducer, computer hardware and software, bar code reader/scanner and the labels which the bar codes are normally printed on (29:3). This section provides a general overview of each of the above components.

Bar Code Symbols. There are a number of symbol types in use today to fulfill the requirements of a variety of special applications (29:3). Most bar codes are horizontal codes consisting of alternating vertical dark and light spaces (17:4). The size, style, color and information content of the symbol types varies considerably (29:3-4). Information is encoded into the bars and spaces by varying their individual widths, with no interpretive information in the height of the bars and spaces.

Since a bar code cannot be read if the path of the scanning device falls outside the barred area, bar heights are chosen to maximize the probability of a successful scan (17:4). All optical bar codes are based upon the principle that darker surfaces reflect less light than lighter surfaces thus they operate via the differentiated reflection of light (29:5). When a scanner emits a light beam and detects light reflections it differentiates between dark bars (absorb light - absence of electrical signal) and light spaces (reflect light - presence of electrical signal). Signal duration is used to determine the width of the bars and spaces (7:3). Bar codes may be read bidirectionally or only unidirectionally. Almost all code versions include a check-sum at the end to prevent erroneous decoding of characters (1).

Some of the versions of the bar code types are the "Two-of-Five", Interleaved "Two-of-Five", Binary, Binary Coded, Bullseye, Uniform Product Code (UPC), Bi-level, "Three-of-Nine" (Code 39), Periodic Binary, Code 128 and Codabar (7:4;1;17:5). Each symbol uses different combinations of bars and spaces to encode information (17:5). Several industries have already standardized the type of bar code symbol they will use and how that selected symbol will be employed. Both DOD and the Health Care Industry have standardized the use of Code 39 and because of this the Code 39 is the bar code symbol concentrated on in this research (23).

Bar Code Equipment. A variety of equipment is employed in a bar code system with the basic hardware being the optical code reader/scanner and the bar coded label (17:6). Some of the other components are the bar code printer, decoders, multiplexers, computers/processors, and label verifiers. These other components represent various levels of sophistication and capability which expand the usefulness of a particular system (29:18). Each of these components is discussed in general terms.

Optical Scanners/Readers. The optical code reader, also referred to as a terminal or a scanner, is a mini-computer which records, calculates, stores and transmits coded data to a main computer (17:7). This component falls into two categories, contact and non-contact readers. Contact readers must either touch or come in close proximity to the symbol. This type reader is usually associated with a wand to scan a bar code symbol. Hence, the name contact readers. This type of reader finds best use when it is not appropriate to convey coded items past a scanner or where the label cannot be placed in an easy-to-view position. Some benefits from using this type of reader are a reduction in the number of clerical errors recording data; a reduction in labor and paperwork to process the data; faster and more accurate inventory taking;

and enhanced efficiency of forms and document control. Contact readers are also often referred to as hand held scanners. Hand held scanners are offered in both portable and stationary versions. Portable units are powered by rechargeable or disposable batteries with entered data stored in solid state memory for later transmission by either direct link or phone line to a computer. Stationary readers can operate in a stand-alone mode or have an active interaction with a host computer. The principle behind the operation of both portable and stationary units are the same. Light emitted from the tip of the device is reflected back and measured. The reflected light is then sent to a decoder where a code analysis is done (7:7-8).

Non-contact readers include fixed and moving beam scanners. Fixed beam readers, as the name implies, use a stationary light source to scan a symbol and unlike moving beam scanners which perform multiple reads, the fixed beam scanner only sees the code pattern once. They are usually mounted in a permanent location, frequently alongside or above a conveyor. The item to be read is normally transported past this type of scanner (17:6;7:6). Fixed beam readers are further subdivided into two types; retro-reflective material and fluorescent light readers. The first type senses marks or codes which consist of a material that reflects light back so that the paths of the returned rays is parallel to those light rays sent at it.

With fluorescent light readers the code to be read is normally the same color as other graphics on the container or item. This keeps the cost of printing the bar code to a minimum. Fluorescent readers are used in high volume sortation systems where color bar codes might not be seen by a laser scanner. Fixed beams are unaffected by bar codes printed in different colors and offer a high degree of accuracy. A moving beam laser scanner employs a light spot to traverse an angular path searching for bar codes on objects. The fast sweeping movement of the beam permits multiple scans to be made on a passing symbol. Read reliability is improved by this method and symbol placement is not critical as long as the location is within the readers field of view or scanning height (7:9).

Bar code readers can identify products moving at speeds that blurr human vision with an accuracy and consistency that defy human involvement (7:3). Even when a human is involved, scanning a bar code is faster and more accurate than manually recording information or keying data into a terminal (1). The nature of the bar code application is of primary importance in the selection of equipment. For inventory control purposes the most widely used reader is the portable, hand-held model (17:7). Based upon tests conducted by the military, moving beam laser scanners were successful in scanning labels covered by polyethelene wrappings of up to an eight mil thichness. This capability is essential for military logistics systems that frequently wrap many items in this material (29:14-15). The quality and type of label is also a factor in the readability of the bar code so it is the next component to be described.

Labels. A label is an adhesive or engraved stamp which furnishes descriptive information about an item. In this context, when label is referred to it is meant to denote the marking of an item with a bar code. Primary concern with affixed labels or label stock is the readability, durability and adhesive quality. Labels can be made of paper, vinyl, or other material depending on the type of surface and environment in which it will be used (17:9). Labels where bar code impressions have bubbles, scratches, blotches, breaks, or other forms of printing anomalies can have a significant impact on a scanning system (29:8). Label contrast between the bars and their background is another factor affecting scanability. Such is the case when red bars are coded over a yellow background. This color combination renders the bar code unreadable. Satisfactory colors for the bar portion of the symbol include black; dark green; brown; and navy, royal, and medium blues. The best background color seems to be white; however, some shades of red and orange are satisfactory for black, navy blue or dark green bars. The use of shiny aluminum to provide either light or dark areas of a symbol should be avoided (29:9).

Printer. Ideally it would be nice for the producer or manufacturer to mark the product with bar coding. However, for many Air Force applications the user will need to print and apply the bar code labels (29:17). When a user of a product prints its own labels it is considered on-site printing (27).

On-site printing is suited to operations requiring little leadtime, great latitude in changing codes and formats, and the flexibility to easily perform batch, sequential, and random order printing. Five of the most common on-site printing techniques are, formed character impact, impact dot matrix, thermal, thermal transfer and laser etch (27:60-61). When the user buys encoded labels from a commercial label printer, it is considered off-site printing (24).

Off-site printing is suited best to operations not interested in printing and requiring large quantities of printed code at the lowest possible cost (24:62). Off-site printing includes letterpress, offset, rotogravure, flexography, and screen printing. Some newer techniques include photographic film imaging, electrostatic dot matrix and laser printing. In deciding between on-site and off-site printing the advantages of application, speed, time, and cost have to be evaluated (24:62-65;27:59-61).

Decoders. Decoders are an essential part of every bar scanning system. The function of the decoder is to convert the electrical signals from the scanner into a useable format, which forms the output to an interface connected to a computer/processor (29:19).

Multiplexers. Multiplexers permit more than one input/output device, i.e. scanner, keyboard, etc., to communicate simultaneously with a host computer via a single communications link (29:19). The number of input/output devices varies depending on the multiplexer, but the key point is that multiplexers support distributed and localized data control (4:74).

Computers/Processors. Data collected by readers/scanners must be stored and analyzed to be of use. That makes the computer an integral aspect of the bar coding system (4:83). In order for a bar coding system to function, a central processing unit of some sort is required (3:43).

Label Verifiers. Before a bar code label is used the accuracy and readability of it needs to be verified. This is extremely important before mass producing label stock and wasting printing costs on bad labels. The verifier performs this function by the use of a pen reader to scan the bar coded label with no useable output generated. It simply checks to determine if the label is scannable and whether the information contained is appropriate (29:19).

Thus far, how the present physical inventory system works and background knowledge about bar code technology and some of its uses has been provided. The next two milestones sets-up, applies and observes these concepts through the performance of trial physical inventories.

IV. Milestone II - Set-up, Procedures Used and Performance of the Physical Inventories

Set-up of Physical Inventories

Two property accounts belonging to the Wright-Patterson AFB Medical Center were selected to perform physical inventories on. The two property accounts were selected because of the willingness of the property custodian to cooperate in the research and because these accounts contained equipment items in varying categories. In addition, the accounts were large enough to allow for a representative sample of times collected. To properly observe the property custodians in their performance of the physical inventory, procedures were set-up that would not interfere with them and so times could be recorded. Also, for each account a custodial receipt locator listing (CRLL) was obtained from the Medical Equipment Management Office (MEMO).

Early in the research, it was intended to take the CRLL and produce a bar code label that would be unique to each item listed on the CRLL. However, efforts to obtain the loan of a bar coding system or the use of a system already in operation failed. This was expected to be the most difficult part of the research. A work-around to provide the same desired results was developed. This work-around was to obtain 80 bar coded labels from the 4950th Logistics Materiel Control Activity (LMCA) and a bar code reader from the Air Force Wright Aeronautical Laboratories (AFWAL) LMCA. These organizations are located in area B of Wright-Patterson AFB, Ohio. Fig 4-1 provides a picture of the Intermic portable bar code reader used.

The bar coded label obtained, contained an alpha-numeric code which represented a line number of an item when listed on a CRLL. The serial number and stock number of a particular item listed on the CRLL would then be associated with this line number. Although a CRLL was not produced to this effect, this is how the present in-use Equipment Management Accounting System (EMAS) at the 4950th LMCA and AFWAL LMCA functions. A stopwatch was used to time the property custodians in the performance of the physical inventory process. The bar code reader was used in the second physical inventory of the two accounts at the medical center.

The objective of performing the physical inventories was to obtain realistic times required for the property custodians to identify each category of equipment listed on their CRLL. Therefore, it was determined that actually loading a CRLL into a bar coding system, producing bar coded labels, reading the labels with a bar code reader, and downloading the inventory into the computer so that it could reconcile the results, were not all necessary to achieve the objective. The purpose of collecting these times was to

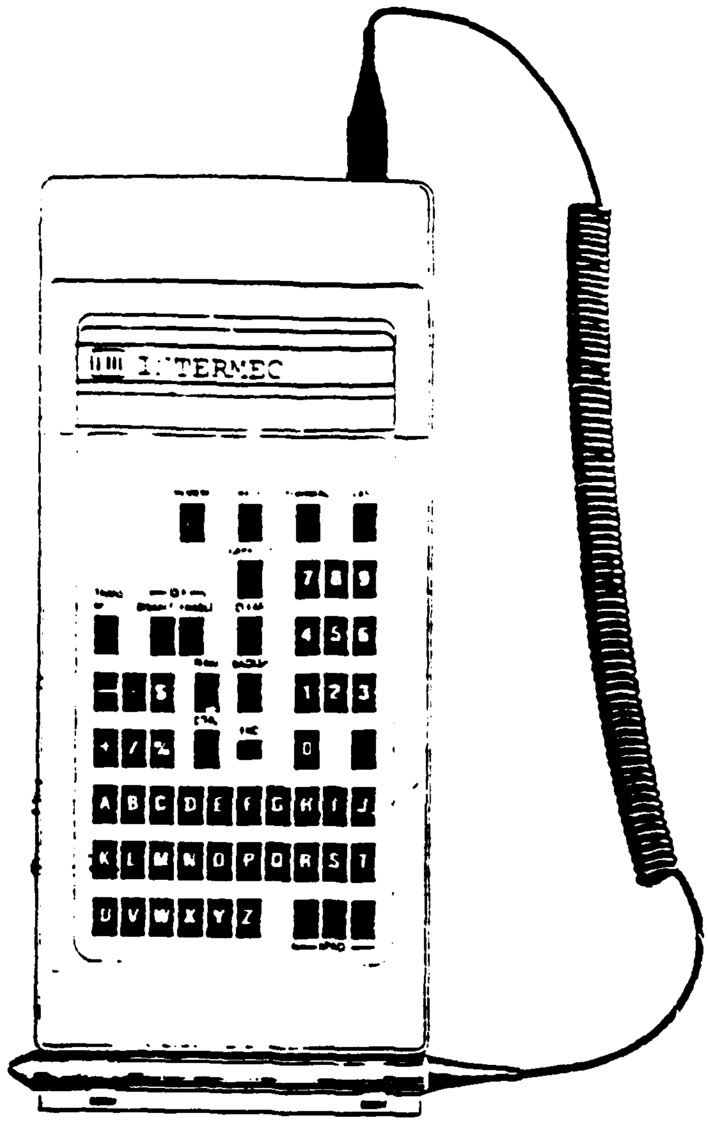

Fig. 4-1. INTERMEC Model 9410B Bar Code Reader

provide a basis for comparing the times it took the property custodian to identify and record a particular item on the CRLL under the present method versus using a bar code reader to obtain the information.

For this reason, arrangements were made with 4950th LMCA and AFWAL LMCA to accompany one of their equipment inventory clerks on the inventory of accounts under their control, in addition to the witnessing of the physical inventories at the Wright-Patterson AFB Medical Center. These two additional activities are presently operating and conducting inventories using the bar code technique. The reasons for including the observation of these inventories were twofold. First, additional times could be obtained on a system already in existence to compare against the results of the trial physical inventory accomplished on the accounts at the medical center. Second, the procedures used by the EMAS at 4950th LMCA and AFWAL LMCA could be observed and recorded.

Procedures Used and Performance of the Physical Inventories

The property custodian, using the CRLL to assist in item identification and to post the finding of the item, began the physical inventory process. As the property custodian began the identification process, the timing was started. When an item was identified and posted to the CRLL, the timing was stopped. The category of equipment inventoried; i.e., stock number controlled only, index number controlled, etc., was identified. After each item was inventoried, the time taken to identify the item, to post the finding to the CRLL, and the category of equipment was recorded. This procedure was continued until all items listed on the CRLL were inventoried.

When the property accounts located at the medical center where intially inventoried, items were tagged with the bar coded label provided from the 4950th LMCA. The procedures used in the first physical inventory were again followed with one exception. The stopwatch was started as the property custodian approached the item he was about to inventory but the method of stopping the timing changed. Instead of the property custodians posting of the CRLL being the prompt to stop the timing, the bar code reader was the cue. The bar code reader gives off a loud distinctive beep when it accepts the bar coded label it is reading and when this distinctive beep was heard the timing was stopped.

This procedure was followed until all items tagged with the bar coded label were read with the bar code reader and all times and observations recorded. This same procedure of observation was used when accompanying the representatives from 4950th LMCA and AFWAL LMCA. In the next milestone, the observations, results and analysis of all of the physical inventories are presented.

V. Milestone III - Results and Analysis of Methods

Results

All physical inventory results using the present method and the bar code technique are summarized in Table 5-1. In the first column labeled "Phy Inv", the "P" after the number represents the use of the present method of physical inventory and the "BC" represents the use of bar coding. Column two labeled "Org Inv", specifies the organization in which the physical inventory was performed. Columns three through six are categories of equipment and within each column there are two numbers; i.e., 23/31.2 represents 23 items inventoried taking a total of 31.2 seconds. This set-up is the same throughout the table. Column seven contains data on the time it took to enter new location codes into the bar code reader. Column eight contains the times recorded for the time walking between rooms.

Observations

Medical Center (MC)

Inventory 1P. In performing this physical inventory, the present method was used. The property account inventoried was the medical logistics activity of the medical center. The first observation made was, that there were several stock numbered items that the property custodian was able to readily identify off the custodial

TABLE 5-1

Summary of Times of Physical Inventories

Phy Inv	Org Inv	#/Time NSN	#/Time INDEX	#/Time ALL	#/Time UNID	#/Time RM ENTRY	#/Time RM WALK
1P	MC	23/31.2	4/54.0	29/626.0	5/98.0	N/A	4/83.0
1BC	MC	23/37.0	4/16.5	29/114.5	5/100.5	N/A	4/83.0
2P	MC	18/164.0	NONE	17/346.0	2/100.0	N/A	18/94.0
2BC	MC	18/104.5	NONE	17/109.0	2/112.0	18/264.0	18/94.0
3P	4950TH	9/73.5	NONE	10/107.0	3/124.0	N/A	NONE
3BC	4950TH	9/13.0	NONE	10/11.5	3/125.5	2/27.0	NONE
4P	4950TH	17/82.0	2/8.0	16/126.5	3/155.0	NONE	NONE
4BC	4950TH	17/14.5	2/2.0	16/14.5	3/158.5	5/90.0	NONE
5BC	4950TH	26/223.5	6/15.5	17/143.5	NONE	4/74.0	3/174.5
6BC	AFWAL	130/433.0	8/15.5	29/146.0	NONE	NONE	33/161.0

receipt locator listing (CRLL) without visually seeing them. These items were consistantly in use. Examples of them are large floor fans, walk-in refrigerators, flat-bed carts, etc.

Because there were no labels affixed showing stock numbers on a majority of the items being inventoried, several had to be identified by the descriptive information listed on the CRLL. Several typewriters and calculators had protective covers on them that had to be removed to identify the serial number and index number. This added to the time necessary to inventory those items. The serial number was not recorded for some items listed on the CRLL and there were five items identified as overages. It was also noticed that there were computer components not listed on this accounts CRLL because they are kept on the CRLL for the Information Systems Office of the medical center.

<u>Inventory 1BC.</u> One of the original assumptions made before this inventory was started was that when all items were tagged during the initial inventory that all pertinent information about them was recorded and entered correctly in the bar code system. This means that the CRLL that would have been produced, had the use of a total bar code system been obtained, would accurately reflect bar codes that would be tied to the items listed on the CRLL.

This was the first time the property custodian had ever used a bar code reader. The initial use caused some difficulty but, after several practice scans the property custodian became more confident in the use and the inventory was started. It was noticed that any film or dirt, either on the aperature of the bar code reader wand or on the bar code label would cause the label not to be accepted or at least delayed the acceptance. This problem was resolved by the wiping of the bar code label with the fingertip, or the aperature tip with a piece of cloth. After this was done the reader would accept the label.

Inventory 2P. Using the present method of performing the physical inventory, the next property account inventoried at the medical center was the surgical clinic. The first observation made about this account was that there were several of the 18 rooms inventoried that had similar equipment layouts. What is meant by this is that there would be a physician's office with an exam room on either or both sides of it. The equipment in these rooms appeared to be standardized; i.e., each patient exam room had an electric patient exam table and each physician's office had a doctor's console or desk. The doctor's console was a stock number controlled item and easily identifiable. Therefore the time required to inventory it was short. The electric patient exam tables had a stock number, index number and serial number and these items took the property custodian longer to inventory because all numbers had to be reconciled against the inventory listing. Another observation made was that the walking time between rooms was held to a minimum because the rooms assigned to the surgical clinic were clustered together. A last observation made in this inventory was that previous problems encountered in Inventory 1P, with the equipment not having a label affixed giving the stock number, were again encountered. This caused the property custodian to identify several items based on their descriptions alone.

Inventory 2BC. Before the start of this inventory, the property custodian was instructed in the use of the bar code reader. With only five minutes instruction the property custodian became comfortable with its use and the inventory was started. The difficulties with the bar code reader not functioning properly because of film on the apperature or dust on the label were not as predominate as in the other inventories with this device. During this inventory in those rooms with several accountable items the property custodian was able to move very quickly from one item to the next. One room which needed to be inventoried was in use and as soon as the procedure being performed was completed, the room was then entered and all items therein were scanned. This was done so quickly that it did not interfere with the next patient. This meant that neither patient care nor the inventory were delayed.

4950th

Inventories 3P;3BC;4P;4BC. The opportunity to observe the 4950th Logistics Materiel Control Activity (LMCA) provided insights into the use of bar coding for inventory purposes. This activity has, within the past year, converted from the present method of taking physical inventory that the medical center is using to the use of bar coding under the Equipment Management Accounting System (EMAS). Due to this recent conversion it was necessary for them to perform both methods of inventory in a single inventory. This means the property custodian accompanied the representative from the 4950th LMCA to confirm that the bar code label that is affixed to the piece of accountable equipment matches what was listed on the inventory listing. If it did, the 4950th representative used the bar code reader to scan and record the label. If it did not, corrections were posted to the inventory listing and the bar code label was scanned.

This situation provided two separate timings. The first represented the time it took the property custodian and the 4950th representative to identify the item and post the inventory listing. The second timing represented the finding of the bar code label and the scanning of it. Even though this did not precisely represent the time it took the property custodian to approach a piece of equipment then find and scan the label, it did conform to one of the assumptions of this research. The assumption was that all labels would be visible and accessible to scan.

Prior to the start of the timings it was agreed between the 4950th representative and the observer that there would be a distinctive break between the two methods so that times could be recorded. The first recorded time was accomplished by starting the timing during the identification and confirming process and stopping it with the posting of the inventory listing. The second cue to start timing came from the 4950th representative. He cued the observer that he was locating the label to scan it. The cue to stop the timing came from the bar code reader as it emits a loud distinctive beep when it accepts the scanning of a label.

This account had some overages that required them to be labeled with a bar code and all information about the overages were posted to the inventory listing. The newly affixed bar code labels were then scanned.

Some difficulties were encountered when performing the inventory with the bar code reader. Dirt or film on either the bar code label or apperature of the wand hampered the reading or accepting of the label by the bar code reader. Also, the location of the label hindered a quick scan. In some cases the label placement was difficult to reach, difficult to find, or both. Other factors that effected the abililty to accept a scan were the size and shape of the item to which the bar code label was affixed. Some small items such as small hand held calculators and a scientific calculator program card reader, had to be hand held or laid on a flat surface to be scanned. The condition of the bar code label would hinder the acceptance of a scan. In one case after several passes over the bar code label, it was decided to replace the label. In this case, the old label was removed and a new one was affixed and scanned. The inventory listing was then posted appropriately to reflect the change.

A last observation of both methods of physical inventory concerns the location of the item to be inventoried. Under the previous inventory method, the location of each item listed on the inventory listing would be confirmed with changes posted to the listing. Under the EMAS, when a location changes it is entered into the bar code reader. Then all items scanned within that area would receive that location code.

Inventory SBC. This physical inventory followed one where the property custodian had been accompanied by the representative from 4950th. This previous inventory took place after the conversion to the EMAS. At that time all reconfirmation of pertinent information about items listed on the inventory listing was done. Therefore, the representative only needed to locate the bar code label and scan it for this physical inventory.

For this inventory, times were recorded on locating the bar code label and scanning it, the entry of new location codes into the bar code reader, and the walking time between rooms. If an item did change location since the last inventory the computer would reflect the change on the next production of the inventory listing.

Previous difficulties noticed in the scanning process were again encountered. Items had to be moved to access the reading of the label, labels were not always in the line of sight and difficult to locate or reach, and several times either the bar code label or apperature of the wand had to be wiped clean.

Air Force Wright Aeronautical Laboratory (AFWAL)

Inventory 6BC. This activity had converted to the EMAS earlier than the 4950th and therefore had already reconfirmed the correctness of the inventory listing. During the inventory of this account, approximately 167 items were scanned and times recorded. This was the first time the representative from AFWAL LMCA used the bar code reader and with relatively little training became efficient enough with the device that recording significant times became difficult. This account had some rooms with numerous accountable items while others contained none. In those rooms with numerous accountable items, the AFWAL representative moved quickly from one item to another. For those rooms with no accountable items, the time that the AFWAL representative spent in each room in search of accountable items was recorded. In this inventory, previously encountered difficulties with the bar code reader occurred again.

General Observation

During the physical inventories two general observations were made. The first was with the reconciliation of the inventory listing after the completion of the physical inventory. The second general observation was with the relationship between the number of rooms inventoried, the number of accountable items within a room, and the intervening space between each room.

The first general observation made was with the EMAS. When all inventory information is transferred from the bar code reader to the computer, the computer processes the input from the inventory and performs a comparison against a master list for the particular account inventoried. Under the present method of physical inventory this is a manual process. The benefit is that the computer does this function much faster with more accuracy. From the comparison, the computer produces a listing which indicates discrepancies with the account. From this listing, inventory discrepancies, such as an item that was transferred from one account to another without the appropriate paperwork, become visible. The property custodians involved can then be told to submit the appropriate documentation to rectify their accounts.

The second general observation made during the inventories was that when rooms were clustered together the inventory went faster. This is shown in Table 5-1 and Table 5-2. Inventories one, two, five and six had walking times between rooms recorded and although these inventories took place in different locations there were similarities between them. Inventories one and five had few rooms with much intervening space between them. Inventories two and six had numerous rooms that were clustered together. Even though there were differencs in walking times based on the proximity of the rooms to one another, the one thing all four inventories had in common was that if a room had numerous accontable items the inventory went faster.

TABLE 5-2

Summary of Time Walking

Inv	#Rooms	Time Walking	Avg
1 *	4	83.0	20.75
2 **	18	94.0	5.22
5 *	3	174.5	58.17
6 **	33	161.0	3.97

* Few rooms with large intervening space between them. Inv 1 & 5 combined = 7 rooms at 257.5 seconds for an average of 36.79 seconds.

** Numerous rooms clustered together. Inv 2 & 6 combined = 51 rooms at 255.0 seconds for an average of 5.00 seconds.

Analysis

An analysis was accomplished from the times recorded in Table 5-1. In this analysis, the times recorded for walking between rooms are not included. No matter which inventory method was used, the property custodian still needed to walk from room to room. The use of bar coding or the present method of physical inventory would not improve the property custodians walking and the times, if included, would mask the comparison between the two methods.

The times for the unidentified equipment are also not included. The reason is because with either method of physical inventory, there normally is always some item that can not be found, immediately located or identified. In reviewing Table 5-1 under the UNID category, one finds that the times recorded under the bar code system are greater than the times for the present method. The times recorded for the bar code system in this category are the times required for the property custodian to identify an item, record all pertinent information, affix a bar code label, then scan it. The difference in time is attributed to the time required to scan the new bar code label. However, this difference in time is considered insignificant. Because of this it was determined that if included, this category would mask the true measurement between the two methods.

Improvements were seen in the three categories, NSN, INDEX, and ALL, with the use of bar coding. In Inventory 1P under category NSN there was an increase in inventory time, but this was attributed to those items within that account that were readily identifiable under the present method and did not have to be visually seen to be inventoried. With bar coding each of these items had to have the bar code label scanned.

In comparing the two different methods of physical inventory, the first four inventories from Table 5-1 were used. Table 5-3 was constructed to compare the times in each category between the two methods. In the category NSN a decrease of 52% (rounded) was observed in the time to inventory this category using bar coding. In the category INDEX, a decrease of 70% (rounded) and in the last category ALL, a decrease of 79% (rounded) in inventory time was observed. Table 5-3 shows that the greater the quantity of information required to identify an item, the greater the probability of time savings with the use of bar coding. This assumes that the bar code label affixed to the item was accurately recorded and is synonymous with the stock number, index number, serial number or combination of all.

Table 5-4 was constructed to compare the overall inventory times from the first four inventories in Table 5-1 for the three categories; NSN, INDEX, and ALL. From this table, one can conclude that the use of bar coding can result in an overall decrease in inventory times ranging from 58% to 85% with the average time expected to be

TABLE 5-3

Comparison of Category Times

NSN

Inv	Present	Bar Code	Difference	% Change
1	31.2	37.0	(5.8)	(0.1858)
2	164.0	104.5	59.5	0.3628
3	73.5	13.0	60.5	0.8231
4	82.0	14.5	67.5	0.8232
Total	350.7	160.0	181.7	0.5181

INDEX

Inv	Present	Bar Code	Difference	% Change
1	54.0	16.5	37.5	0.6944
2	NONE	NONE	NONE	NONE
3	NONE	NONE	NONE	NONE
4	8.0	2.0	6.0	0.75
Total	62.0	18.5	43.5	0.7016

ALL

Inv	Present	Bar Code	Difference	% Change
1	626.0	114.5	511.5	0.8171
2	346.0	109.0	237.0	0.6849
3	107.0	11.5	95.5	0.8925
4	126.5	14.5	112.0	0.8854
Total	1205.5	249.5	956.5	0.7930

TABLE 5-4

Comparison of Inventory Times

*Inv	**Present	Bar Code	Difference	% Change
1	711.2	168.0	543.2	0.7638
2	510.0	213.5	296.5	0.5814
3	180.5	24.5	156.0	0.8643
4	216.5	31.0	185.5	0.8568
Total	1618.2	437.0	1181.2	0.7299

* Only inventories one through four times are used

** Times are combined NSN, INDEX & ALL category times

approximately 73%. In reviewing Tables 5-3 and 5-4, there is an indication that the amount of decrease is dependent on the quantity of items in a particular category. It was additionally observed, based on the information in Tables 5-2 and 5-3, that during these inventories the closer the rooms and the greater the number of accountable items within a room the faster the bar code inventory went, especially if the items in the room fell into the ALL category.

To construct Table 5-5, which was required for the simulation models in Milestone IV, the following further analysis was accomplished from Table 5-2. The number of items in each category and for both methods of inventory where totalled. The totalled times were then divided by the totalled number of items within a particular category and

TABLE 5-5

Average Inventory Times Per Category

Present

NSN	INDEX	ALL	UNID	WALK
4.0	1.0	18.0	37.0	9.0

Bar Coding

BC	ENTRY	UNID	WALK
4.0	16.0	38.0	9.0

inventory method. These average times were than rounded to the nearest whole integer.

In the previous milestones the present method and the bar code technique were explained, explored and demonstrated. The next milestone addresses these concepts through the technique of modeling.

VI. Milestone IV - Development of Simulation Models[1]

Objective

The objective of the simulation models constructed is to represent the characteristics of the present method of performing physical inventories and the characteristics in the use of bar coding to perform physical inventories. These models can be used to compare the two different methods of performing physical inventories and to estimate projected savings in money, manpower and time. This information would aid in justifying the capital outlay to implement a bar code program in the medical logistics field.

Input Data

To obtain input data in building the simulation models, and to specify parameters, different methods of data gathering were employed. The first method was to obtain current custodial receipt locator listings for the various property accounts at the Wright Patterson AFB Medical Center. Custodial receipt locator listings (CRLLs), dated 5 February 1986, on 52 property accounts were obtained through the MEMO. Each custodial receipt locator listing was analyzed and each item listed within the listing was categorized as being, stock number controlled only (NSN),

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[1]The information in this section is technical in nature and the reader should refer to the glossary in Appendix B.

stock number and index number controlled (INDEX), or stock number, index number and serial number controlled (ALL). A total count was taken within each category and this data was used to build the computerized spread sheet shown in Table 6-1.

TABLE 6-1

Spreadsheet Analysis of Property Accounts

ACCT #	TOTAL INDEX	TOTAL ALL	TOTAL QTY	%TOTAL INDEX	%TOTAL ALL	%TOTAL NSN	TOTAL% CNTRL
101	2	62	75	3%	83%	15%	85%
104	0	142	154	0%	92%	8%	92%
121	3	60	74	4%	81%	15%	85%
122	3	33	38	8%	87%	5%	95%
123	3	58	66	5%	88%	8%	92%
131	3	92	112	3%	82%	15%	85%
132	0	9	13	0%	69%	31%	69%
141	1	68	77	1%	88%	10%	90%
142	5	40	69	7%	58%	35%	65%
151	6	58	72	8%	81%	11%	89%
177	20	17	105	19%	16%	65%	35%
178	8	16	63	13%	25%	62%	38%
24A	9	48	164	5%	29%	65%	35%
24B	19	39	71	27%	55%	18%	82%
380	3	48	79	4%	61%	35%	65%
401	5	9	39	13%	23%	64%	36%
402	51	34	135	38%	25%	37%	63%
403	2	26	44	5%	59%	36%	64%
404	51	62	191	27%	32%	41%	59%
411	35	87	228	15%	38%	46%	54%
412	6	9	41	15%	22%	63%	37%
414	2	11	31	6%	35%	58%	42%
422	1	14	28	4%	50%	46%	54%
431	13	28	74	18%	38%	45%	55%
436	58	69	197	29%	35%	36%	64%
439	5	25	54	9%	46%	44%	56%
471	0	16	38	0%	42%	58%	42%
475	7	13	48	15%	27%	58%	42%
492	0	6	7	0%	86%	14%	86%
511	146	264	651	22%	41%	37%	63%
513	44	25	80	55%	31%	14%	86%
61A	9	38	67	13%	57%	30%	70%

TABLE 6-1

Spreadsheet Analysis of Property Accounts (cont.)

ACCT #	TOTAL INDEX	TOTAL ALL	TOTAL QTY	%TOTAL INDEX	%TOTAL ALL	%TOTAL NSN	TOTAL% CNTRL
622	21	69	112	19%	62%	20%	80%
623	6	31	41	15%	76%	10%	90%
632	36	29	89	40%	33%	27%	73%
651	2	89	117	2%	76%	22%	78%
661	1	60	62	2%	97%	2%	98%
662	108	125	403	27%	31%	42%	58%
672	2	13	78	3%	17%	81%	19%
682	18	7	111	16%	6%	77%	23%
684	13	86	147	9%	59%	33%	67%
690	3	18	32	9%	56%	34%	66%
722	69	9	121	57%	7%	36%	64%
741	31	10	59	53%	17%	31%	69%
761	16	69	118	14%	58%	28%	72%
781	18	7	180	10%	4%	86%	14%
79B	2	2	9	22%	22%	56%	44%
790	32	30	103	31%	29%	40%	60%
846	6	12	51	12%	24%	65%	35%
851	26	68	170	15%	40%	45%	55%
852	2	14	38	5%	37%	58%	42%
855	1	6	19	5%	32%	63%	37%
TOTALS	933	2280	5245	18%	43%	39%	61%

From this spreadsheet, five property accounts containing items with varying accountability were selected. These accounts were selected because they contained a mixture of stock number, index number and serial number controlled equipment items within them. The property custodians for these accounts were then contacted and asked a series of questions pertaining to the number of rooms in which property was kept, their estimate of the time spent walking between rooms, approximate number of items within each room, and the approximate time required to inventory each category of property listed on their account (8;16;18;21;22). Responses to each question varied, but in general the estimates are summarized into Table 6-2.

TABLE 6-2 - PRESENT METHOD OF PERFORMING PHYSICAL INVENTORY

		Low	Avg	High
# of Rooms (each)	:	1		30
# of Items per room	:	5		20
Time walking to rooms	:		30	
Time Required to Inventory (seconds):				
Stk # Controlled	:	10	20	30
Stk & Index # Controlled	:	20	30	40
All Three Categories	:	30	60	90

The property custodians indicated that, at times, items could not be identified or found during inventories. They further said these items consume a large proportion of the inventory time. Some reasons provided for not finding items included item misplacement in another room and the item missing entirely or being stolen. A majority of the time items were either misplaced, misidentified or were highly mobile and not available at the time they were to be counted. Only time statistics provided by the property custodians contacted on those items that could be readily identified were recorded and no consideration was given to those items lost to theft. The times submitted by the custodians had a wide variance. For those items that initially could not be located, a time to locate them was set between 900 and 3600 seconds. It later was reduced to 60 to 900 seconds because the outputs from the simulation model appeared to be high. From information obtained from the Director of Medical Logistics at the USAF Medical Center, Wright-Patterson AFB and AFM 67-1, Vol V, which governs the medical logistics operation pertaining to the appropriate methods for performing physical inventories, Model I was constructed (15). The times recorded in the tables in this section were compared with the times observed in Table 5-1 through Table 5-5 and the final times used for Model I were the ones shown in Table 5-5.

The next model built simulates the use of bar coding in performing a physical inventory. To obtain data to construct this model, information from the literature search in Milestone I was reviewed, then both users and knowledgeable individuals familiar with the applications of bar coding were contacted (9;14;20;26). Time periods involved with reading/scanning a bar coded label varied with the type of equipment used. The condition of the label could also vary the time required. An unreadable label would cause manual entry of information into the scanning devices keyboard or the attachment of a new label. The location of the label would also vary the inventory time. It is assumed for this model that all labels are accessible but not all labels are readable. In cases where no label was available to identify a piece of equipment, the item was placed in the unidentifiable category as in Model I. From the information gathered, Table 6-3 was constructed. The times in Table 6-3 were compared with those in Table 5-5. The times in Table 5-5 are based on information obtained during the trial physical inventories. The times in Table 6-3 are based on estimates. Because of this, it was reasoned that the averages in Table 5-5 would result in a more accurate model simulation of the two methods.

TABLE 6-3 - BAR CODE METHOD:

Time required for Inventory:	Low	High
Labeled item (seconds)	1	5
Non-readable Label	5	15
Unidentifiable	15	60

Model Construction

Assumptions. Before either model could be constructed certain assumptions were made. The first was that labels, when available were visible and either readable or non-readable and each of those two categories would receive a different time value. A second assumption was that no concern would be given to those items normally not found during inventory. It was assumed all items would eventually be identified. The third assumption made on both models was that the same basic procedures for performing both types of physical inventory would be followed.

Model I - Present Method of Physical Inventory. Figure 6-1 shows the flow graph for this model with Appendix C containing the simulation coding. In the coding, global variable XX(1) in this model was set at 100. This variable would then act as a control mechanism to be compared against a counter in the model to insure that a minimum inventory simulation of 100 items would be accomplished. A seed was specified so Model I and Model II could use the same random number stream. One entity was created and this simulated the property custodian. The next step was to simulate the time it takes the property custodian to walk from room to room.

Normally, in medical facilities homogeneous services are clustered together for the convenience of the patients. This also clusters the rooms and equipment items assigned to these services. As a result, very little time is wasted by the property custodian walking between rooms that require inventoring. This distribution of rooms is reasoned to have an exponential distribution. The probability that the rooms are clustered together is greater in the beginning and because of this cluster effect the probability of the property custodian having to walk a further distance decreased as the distance between rooms became greater. Once the property custodian (entity) arrived at a room he is faced with a number of items to inventory.

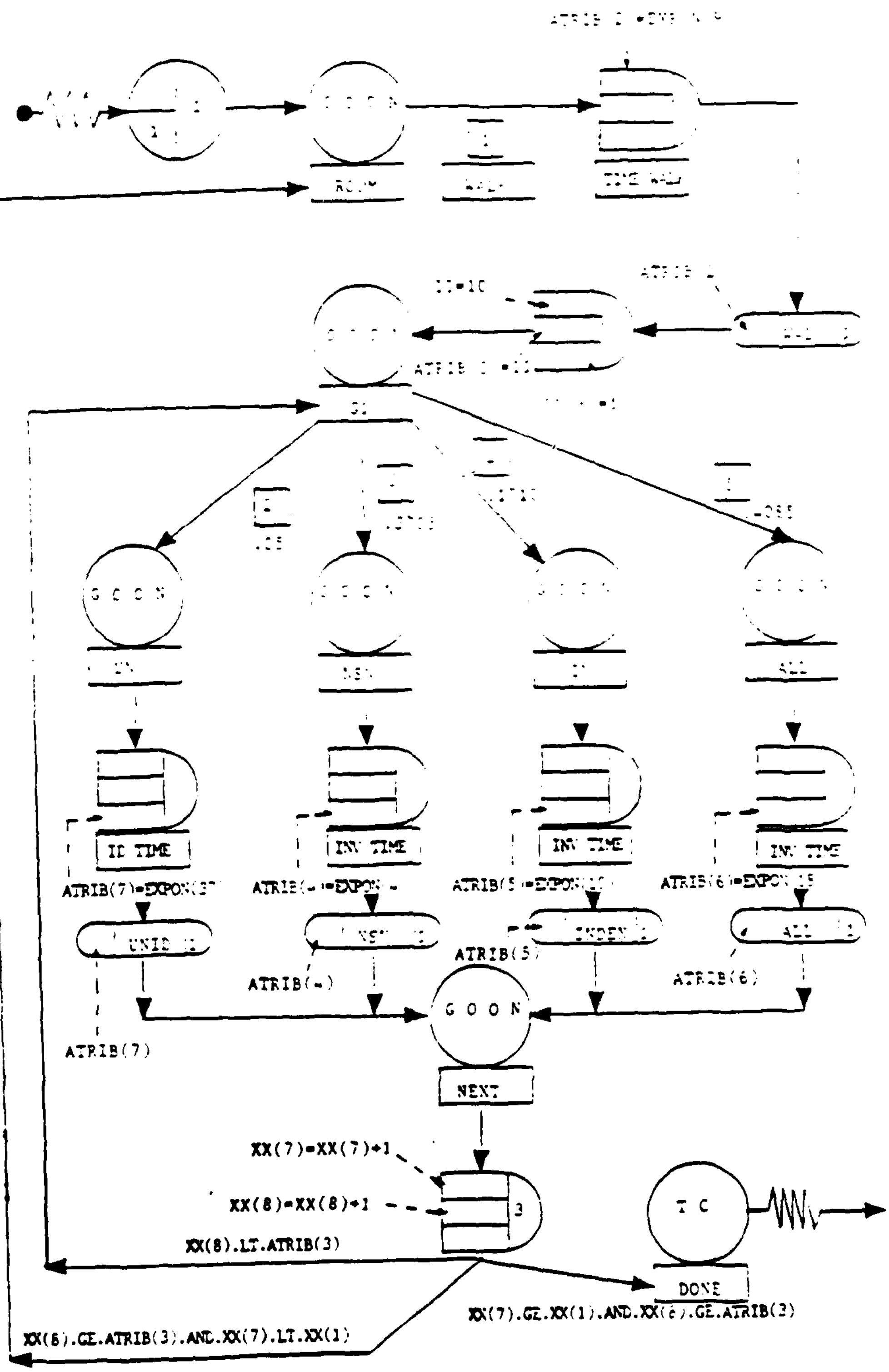


Fig. 6-1. Model I Flow Graph

From the data collected and shown in Table 6-2, an estimate of the range of items contained in the rooms was formulated. There appeared to be a uniform distribution, or equal probability of there being from five to twenty items contained within each room. For this reason integer global variable II was set at ten. This was done to keep the average number of items per room at approximately ten. The statement used to do this was an assign statement and it established attribute two at ten for control purposes. The control establishes a number of items in a room which are compared against a counter in the model. The model then knows when it has inventoried everything within a room. The next step in the model was to initialize the counter for the number of rooms to be inventoried.

With all counters set and the time taken to walk to the room established, the next step was for the property custodian (entity) to inventory the items. This is where the probability branching begins. It takes a varied amount of time for a property custodian to identify a piece of equipment. In some cases a piece of equipment is not readily identifiable and takes a much longer time period to inventory and identify. In activity two, this time is simulated. Assuming 95% of the inventory is identified, a 5% probability of an item not being indentified was established.

In activities three, four and five the probabilities used are based on the empirical data shown in Table 6-1 with 5% in each category removed so that 100% is not exceeded; i.e., 5% + 37% + 17% + 41% = 100%. From this probability branch node the entity takes one of four paths. The time factor assigned when the entity reaches the node it is going to simulates the amount of time required to identify an item, inventory it and to post the inventory listing. All times generated for the different categories were with an exponential distribution. The main reason for using an exponential distribution is that trial runs produced negative inventory times for some items. This is an impossibility so the exponential distribution is used to simulate the times required and will not generate negative times. Once a time factor was assigned it was collected.

The entity is then routed to another GOON node labeled "Next". The counter for the number of items inventoried is then incremented and conditional statements are compared with counters for the number of rooms and items inventoried. If all items in a room were not inventoried, the model would branch back up to the label "G1", where the probability branching process described is accomplished again. If all items within a room were inventoried, then the room counter is incremented. If there are rooms remaining to be inventoried, the model would branch back up to the label "ROOM". Here the process of walking to a room, assigning the number of items within this room, and reinitializing the counter for the number of items is accomplished.

This conditional branching continues until the total number of items specified by XX(1) and the number of rooms are both satisfied. Each time a run was completed the MONTR, CLEAR statement would reset all registers to prepare them for the next run.

Model II - Bar Coding Technique of Physical Inventory. Figure 6-2 contains the flow graph and Appendix D contains the coding for this model. The intial steps of Model II are identical to Model I up to activity two. Activity two simulates the time it takes the property custodian to enter a new location into the bar code reader. The time for this was extracted from Table 5-5. The next difference in Model II from Model I is at the probability branch node.

At the probability branch node, only two paths are taken. One path is the unidentifiable item branch and it again received a 5% probability. Due to the nature of bar coding it was not necessary to distinguish between the different categories of equipment as in Model I because all information needed to identify a piece of equipment is encoded into the bar coded label. However, if a label is damaged in such a way the scanner can not read it, the information would need manual entry into the reader/scanner or a new label attached. After the entity branched to the

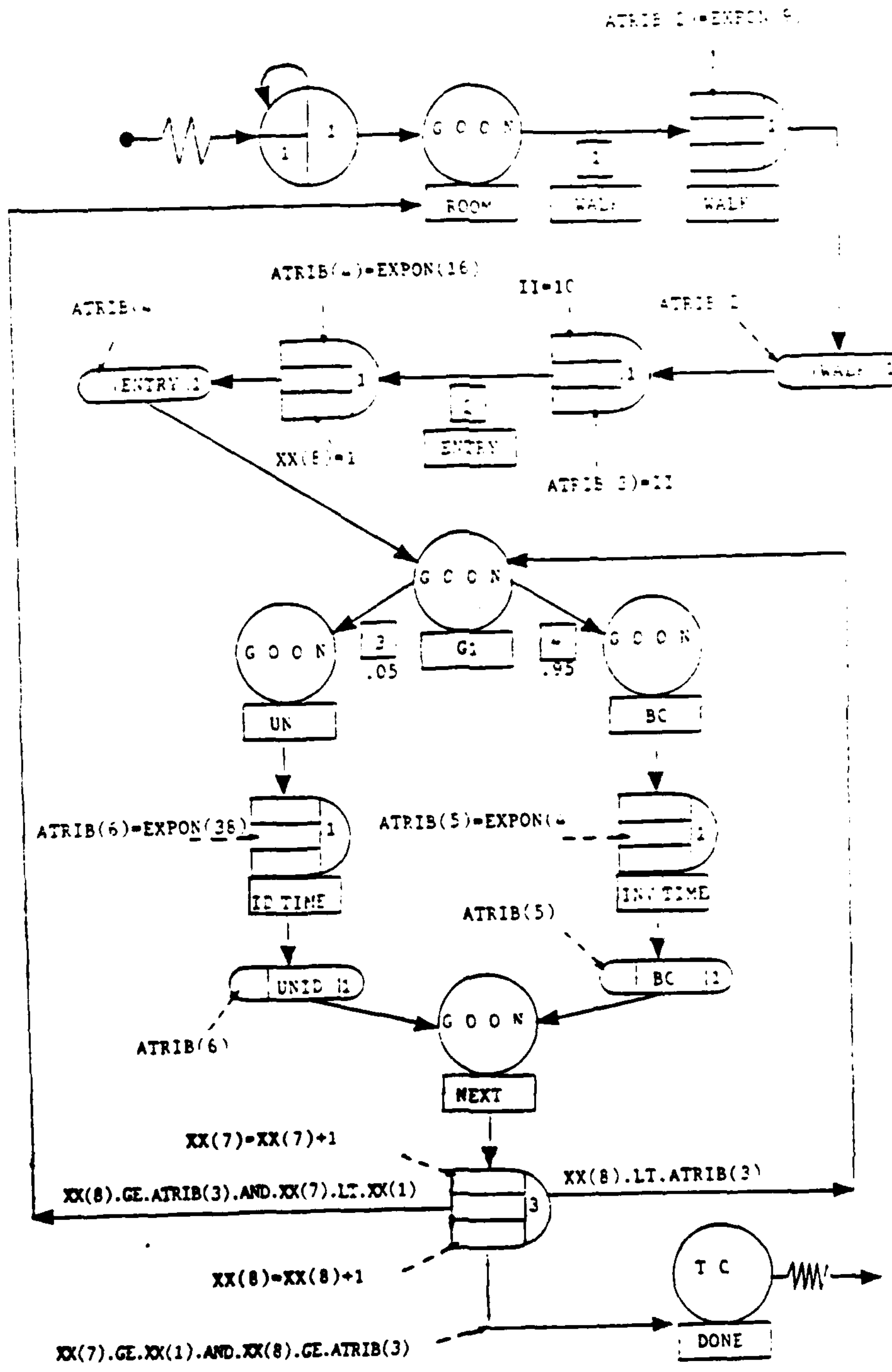


Fig. 6-2. Model II Flow Graph

selected category it then followed the same cycling procedure stated in Model I.

Verification/Validation

Once both model flow graphs, shown in Figures 6-1 and 6-2, were constructed a comparison of the structure against the actual procedure was accomplished. This was done by acting like the entity moving through the model and seeing if it followed the logic of the procedual guidance gathered. After completing this step, the code was written and input into the CSC. The model was then run through a short SLAM queue to check for coding errors. Once this was done a multiple run was accomplished with a MONTR, TRACE statement. The output from this simulation run was then analyzed.

The first thing to be checked was whether the models followed their associated flow graph. Next a check was made on all random number generators to assure they were performing within the parameter specified. Once these problems were corrected, a series of runs on each model with the number of rooms increased by five was accomplished; i.e., five runs at five rooms, five runs at ten rooms, five runs at fifteen rooms, etc. This was done to stress the model and see how it would react. Upon analysis of the output it became apparent an initial time specified to identify equipment placed in the unidentified category was excessive. This time was adjusted downward from a range of

900-3600 seconds to 60-900 seconds and then again adjusted down to what is shown for this category in Table 5-5.

Experimentation

Since the seed in each run was specified, the number of rooms and total items fixed, and with the knowledge of times established, it was determined that a warm-up period was unnecessary. However, the pilot runs specified above were useful in detecting the problem with times in the unidentified equipment category. Having made what was felt as final adjustments and calibrations to the models, a series of runs were accomplished.

In further experimenting with the final model, it was decided to make ten runs of each model and do this three times. The first time the models were run, the probability rates for each category were adjusted so that 10% of all items inventoried would fall into the unidentified category. The second run adjusted the unidentified category probability to 5%. On the last multiple run, this category was set at a 1% probability. This was done to see the effects of inventory accuracy on the model results. The results were not surprising. When the probability of those items which took a longer period of time to inventory increased, so did the overall mean time of the model and vice versa.

After this was accomplished it was decided to make the final runs of the models. These multiple runs were accomplished with the probability rates adjusted appropriately so 5% of the items inventoried would fall into the unidentified category. The 5% probability rate was decided upon based on the results and observations during Milestone III. Each model was set to run ten times and the number of rooms and number of items that would be generated was fixed at 12 and 108 respectively. The printouts of these simulation runs are in Appendices E and F.

Output Analysis

From the final model runs, the information in the SLAM II SUMMARY REPORT section was reviewed. In analyzing the mean values, it was concluded the time assigned for the unidentified (UNID) items, the walking time (ACT/1), and in the case of the bar code model, the category entry (ACT/2), masked the true statistics being sought. The information desired was on the estimated time it would take to identify and record an item under both methods. For this reason the statistics gathered from Model I were on categories; NSN (stock numbered item only), IN (stock & index number controlled) and ALL (stock, index, & serial number controlled) items. In Model II, statistics on BC (bar coded item) were collected.

In researching the technique of bar coding, a decrease in inventory time required of 50% or more would not be unlikely. The null hypothesis used in this project was that the difference in the mean times between the two models would be zero and the alternate hypothesis was that they would not be equal to zero. The detail of the analysis accomplished in this project is in Table 6-4. From this analysis an improvement in time of 88% was observed and a test of equality of the variances indicated rejection of the null hypothesis. Therefore, the differences in the mean times between the two models are not equal to zero.

Conclusions

Based on the output and analysis of the models, there appears to be a significant difference in the two methods of performing physical inventories. The bar code model supports the belief that increased efficiency can be gained with the use of bar coding. The 88% improvement in inventory time from the simulation models supports the findings in Milestone III.

TABLE 6-4

Analysis of Simulation Model Runs

Category	1	2	3	4	5	6	7	8	9	10
NSN	3.722	5.439	4.698	4.799	4.839	5.841	5.769	4.178	6.654	3.805
INDEX	9.871	16.55	11.36	10.21	13.76	9.236	9.086	10.87	6.979	12.01
ALL	15.83	13.78	18.47	15.59	24.04	20.18	17.67	15.1	15.41	15.7
Total	29.432	35.769	34.528	30.599	42.639	35.257	32.525	30.148	29.043	31.515

Mean = 33.1446 Var = 16.9533 St Dev = 4.1174

Category	1	2	3	4	5	6	7	8	9	10
BC	3.636	3.541	4.297	3.965	3.841	4.137	3.868	3.535	3.744	3.691

Mean = 3.8255 Var = 0.063 St. Dev = 0.251

Test on Equality of Variances : $\frac{16.9533/10}{.063/10} = 269.1$

% Change in Methods : 1 - (3.8255 / 33.1446) = 88%

VII. Conclusions and Recommendations for Further Research

The conclusions of this research provide the answers to the research questions that formed its basis. Research questions one and two asked if the present method of performing physical inventories is the most efficient and if not, are there more efficient methods in use. The answer to research question one is "no", with "yes" being the answer to research question two. Research questions three and four asked what methods are civilian health industries using and are they developing more efficient methods for physical inventories, respectively. The answer to both questions three and four is that the health care industry has adopted a bar code standard and is pursuing its use. Research questions five, six and seven asked if similar methods of advanced physical inventories are in use in the Air Force, DOD, or other Federal agencies. If so, are they adaptable to the Air Force medical field and if applied to medical logistics will they increase efficiency. The answer to all three of these questions is, "yes".

Research questions one through seven are answered by what was found and stated in Milestone I, Milestone III, and Milestone IV. In Milestone I, the literature search, it was shown that both DOD and the civilian health care industry have adopted the bar code symbol 3-of-9 as their standard. The LOGMARS program of the DOD is well established and the number of applications for use are increasing constantly. The civilian health care industry is now exploring and actively pursuing its use. Additionally, Milestone I showed that during a test period at the Defense Depot in Ogden, the use of bar coding for inventory and location survey of three thousand storage locations resulted in a 6% productivity improvement in data collection as well as decreased processing time for data reconciliation with improved data accuracy. The Concord Naval Weapons Station found that by using bar coding for inventory of ammunition they could reduce the cost of conducting inventory by 80% over conventional methods for inventorying the same material. The DOD realized an estimated savings in 1982 of $113.9 million by using bar coding versus conventional methods. From the trial inventory documented in Milestone III the decrease in inventory time required ranged from an estimated 58% to 86% with the overall combined average estimated at 73%. The analysis of the simulation models in Milestone IV indicated an 88% improvement in inventory efficiency with the use of bar coding. Based on the findings stated, the present method of performing the physical inventory of property under the control of the Medical Equipment Management Office (MEMO) does not appear to be the most efficient.

Research questions five, six and seven asked if similiar methods are now in use in the USAF, DOD and Federal government and whether they are adaptable to use in the USAF medical field. In Milestone I, examples were given of the use in the federal government and DOD. In addition, the actual use of the Equipment Management Accounting System (EMAS) by the 4950th Logistics Materiel Control Activity (LMCA) and the Air Force Wright Aeronautical Laboratories (AFWAL) LMCA were observed and documented in Milestone III. The simulation model developed in Milestone IV and the trial inventories accomplished in Milestone III provide adequate proof that this technology can be used in the medical field for inventory control of MEMO controlled equipment. The results from the trial inventories in Milestone III and the simulation model analysis in Milestone IV show that the use of bar coding can improve the efficieny and accuracy on physical inventories and is applicable to medical logistics.

Conclusions drawn during this research are that the more complex the structure of the property account and the greater the number of equipment items, the greater the benefits when using bar coding. Those property accounts that have numerous rooms clustered together, or a high density of equipment within a particular area, or both, would benefit the most. The accuracy of the inventory is also essential to the effective use of bar coding. If an account has numerous items which were not on an inventory list or are unidentifiable, this will have an adverse effect on the efficient use of bar coding.

Bar coding is accurate, if all items within an account have been tagged properly and the bar code label properly reflects the pertinent information listed on the inventory listing. Bar coding is efficient, if the bar code labels to be scanned with a bar code reader are accessible and are readable. Bar coding is effective, if the users of the bar code system trust and have faith in it and do not find it necessary to reconfirm serial numbers, index numbers, and stock numbers every time they perform an inventory. These users must insure that personnel do not pick bar code labels off property. If an individual performing a physical inventory using the bar code technique, finds it necessary to stop and manually identify an item, this hampers the overall effectiveness and efficiency of the inventory.

The administrative workload associated with being a property custodian, especially the amount of time necessary to track and physically inventory equipment, distracts individuals from their primary duty of patient care. By evaluating the present method of performing a physica inventory against the more advanced use of bar coding, a comparison was made.

The overall objective of this research project was to verify that bar coding of equipment under the control of the Medical Equipment Management Office (MEMO) would result in greater inventory control, reduce the administrative burden, increase accuracy, improve efficiency and decrease the time required to perform physical inventories. The results provided by this research strongly support that bar coding of property under the control of the MEMO will provide the desired objectives.

Based on the findings of this research that support the use of bar coding for the efficient performance of physical inventories on MEMO controlled equipment, the next logical step is research into the feasibility of implementation. It is recommended that a follow-on thesis be conducted to look into the feasibility and financial impact of implementing a bar code system for the inventory control and management of MEMO equipment at all USAF Medical Equipment Management Offices.

Appendix A: Glossary of Bar Code Symbol Terminology (1)

Aperture - A scanner's aperature is the opening through which the relected light enters the unit. The aperature determines the diameter of the light spot reaching the bar code. Proper aperture size selection is critical to the system. It must be matched to the nominal bar size.

Bar - The darker, non-reflective element of a bar code.

Bi-Directional Symbol - A bar code symbol format which permits reading in opposite directions across the bars and spaces.

Check Digit - A calculated character included within the bar code for error detection. It may also be referred to as Checksum Character.

Code Density - The number of data or message characters which can be represented per unit length of space.

Continuous Code - A bar code which does not have inter-character spaces as part of its structure.

Depth of Field - The difference between the minimum and the maximum distance from the scanner that a bar code can be read. Can be compared with the depth of field of a photographer"s lens. Does not apply to wand scanners since they require contact with the symbol surface.

First Read Rate - The percentage of correct readings that will be obtained in one pas of the scanner over the symbol.

Fixed Beam Scanner - A stationary bar code scanner which uses a fixed beam of light to read bar code symbols. The symbol must be moved through the light beam to be read.

Hand-Held Scanner - A scanner held and operated by a human operator, enabling the scanner to be brought to the symbol.

Inter-Character Space - The space between the bars or spaces which represent different characters in a discrete character bar code.

Mis-Read - A message which is decoded incorrectly and transmitted to the host computer. The transmitted data does not agree with the encoded data.

Module - The narrowest element (bar or space) in a bar code. The nominal dimension.

Moving Beam Scanner - A stationary bar code scanner which uses moving light beam to dynamically scan and decode a bar code symbol.

Nominal Dimension - The width of a narrow bar or space.

No-Read - A scan attempt which does not result in a successfully decoded symbol.

Quiet Zone - An area before the start character and after the stop character which is devoid of printed material. This may also be referred to as Margin.

Space - The lighter, reflective element of a bar code.

Start Character - A special pattern of bars and spaces used to identify the beginning of a bar code symbol.

Stop Character - A special pattern of bars and spaces used to identify the end of a bar code symbol.

Voids - Light areas in the bars of a bar code symbol which are usually caused by printing errors.

Wide-To-Narrow Ratio - The ratio between the width of the wide elements and narrow elements.

Appendix B: Glossary of Simulation Terminology and Symbols

Terminology

Activity - represents a time period of specified length (6:6).

Entity - is an object of interest in the system (6:6).

Attribute - is a property of an entity (6:6).

State of System - the collection of variables necessary to describe the system at any time, relative to the objectives of the study (6:7).

CSC - Classroom Support Computer is a Digital Equipment Corporation (DEC) VAX 11/785 running the Virtual Memory System (VMS) operating system (2:5.1).

GOON node - allows entities to continue on from one activity to the next sequential activity (19).

Colct node - when an entity reaches this node, statistics based on obsevations are recorded (19).

Create node - creates teh entities which flow through the network (19).

Terminate node - this node destroys or deletes entities from the network. Entities from various points of the network can be routed to a common terminate node (19).

Assign node - set values of attributes of entity and sets values of global variables in network (19).

Simulation - The imitation of the operation of a real world process over time, involves generating an artifical history of the system, observing the history and drawing inferences about the system (19).

Model - A collection of theories about the operation of a system. The theories describe the system's content (entities) and the relations (mathematical, logical) between the entities (19).

Seed statement - purpose is to permit the user to specify the starting unnormalized random number seed for any of the 10 random number streams available within SLAM and to control the reinitialization of streams for multiple simulation runs (25:149).

SLAM network model - The framework is a network structure consisting of specialized nodes and branches. They are a representation of a process and the flow of entities through the process (25:79).

Branches - represents the passage of time and is the graphical representation of activities. They emanate from nodes and show the path entities take (25:80).

Nodes - used to represent the arrival event, delays or conditional waits, the departure event, and other typical system actions (6:99-100).

Node labels - used to identify non-standard flows of entities, they are used as statement labels in a fashion similar to statement numbers in a FORTRAN program. Then can be appended to any node (25:85).

Flow graph - a graphical representation of how a system or network works and interracts using nodes, branches, and symbols.

Probabilistic branching - is when two or more branches emanating from a node have a probability assigned to them that the entity will take them (25:85).

Conditional branching - is when a branch has a condition specified to it and if the entity meets that condition it will take that branch (25:85).

SLAM - is a high-level, FORTRAN-based simulation language which allows an event-scheduling or process-interaction orientation, or a combination of both approaches (6:99).

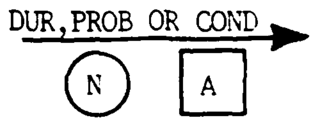
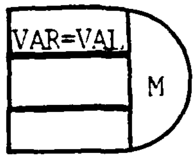
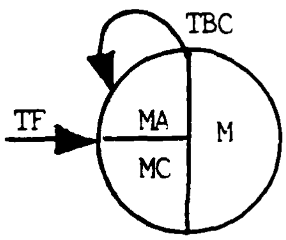
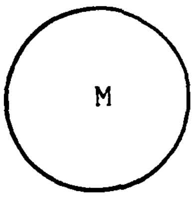
Global variable - is set in one portion of the network and can be used at any other portion of the network. Usually stated as XX(I), a value of global variable I, or II, which is an integer global variable (6:92-94).

MONTR statement - used to monitor selected intermediate simulation results. It can be used to clear statistical arrays after a "warm up" period in order to reduce any bias that is due to intial starting conditions (6:151-152).

CLEAR option - this is a MONTR option which causes all statistical arrays, including the file statistics, to be cleared (6:152).

TRACE option - this is another MONTR option that causes the starting and stopping of detailed tracing of each entity as it moves through the network (6:152).

Symbols (25:130-132)

Name	Symbol	Statement
Activity		ACTIVITY,(N)/A,DUR,PROB or COND,NLBL
Assign		ASSIGN,VAR=VALUE, VAR=VALUE,M
Collect		COLCT,TYPE or VAR,ID,NCEL/HLOW/HWID,M
Create		CREATE,TBC,TF,MA,MC,M
GOON		GOON,M
Terminate		TERMINATE,TC
Node Label		NLBL

Definition of Codes

N	Number of parallel servers
A	Activity number
VAR	SLAM VARiable
M	Max number branches entity can be routed from a node
TYPE	Statistics TYPE to be collected
ID	IDentifier
H	NCEL/HLOW/HWID
NCEL	Number of interior CELls of a histogram
HLOW	Upper limit of first cell of a histogram
HWID	Cell WIDth for a histogram
TF	Time of First creation
TBC	Time Between Creations
MA	Mark Attribute for creation time
MC	Maximum Creations to be made
NLBL	Node LaBeL

Appendix C: Model I SLAM Coding

```
GEN, T.W. BECKWITH, INVENTORY METHODS, 07/03/86,10;
LIMITS,1,8,150
INTLC,XX(1)=100;
SEED,9375295(1)/YES; TO SYNC RUNS
NETWORK;
;==================================================
;          PROPERTY CUSTODIAN AND #ITEMS IN ROOM
;==================================================
       CREATE,,,1; GENERATE PROPERTY CUSTODIAN
ROOM   GOON;
       ACT/1,; WALKING TIME BETWEEN ROOMS
       ASSIGN,ATRIB(2)=EXPON(9);
       COLCT,ATRIB(2),WALK,,;
       ASSIGN,II=10,ATRIB(3)=II; # ROOMS
       ASSIGN,XX(8)=1; COUNTER FOR #ROOMS
G1     GOON;
;===================================================
;         PROBABILITY BRANCHING OF CATEGORIES OF ITEMS
;===================================================
       ACT/2,,.05,UN; 5% PROB
       ACT/3,,.3705,NSN;
       ACT/4,,.1710,IN;
       ACT/5,,.4085,ALL;
;====================================================
NSN    GOON; STOCK # ITEM
       ASSIGN,ATRIB(4)=EXPON(5); INV TIME REQUIRED
       COLCT,ATRIB(4),NSN,;
       ACT,,,NEXT; GO TO NEXT LABEL
;====================================================
IN     GOON; INDEX # ITEM
       ASSIGN,ATRIB(5)=EXPON(10); INV TIME REQUIRED
       COLCT,ATRIB(5),INDEX,,;
       ACT,,,NEXT; GO TO NEXT LABEL
;====================================================
ALL    GOON;  INDEX, STK# & SERIAL # CONTROLLED
       ASSIGN,ATRIB(6)=EXPON(18); INV TIME REQUIRED
       COLCT,ATRIB(6),ALL;
       ACT,,,NEXT; GO TO NEXT LABEL
;====================================================
UN     GOON; UNIDENTIFIED ITEM INVENTORY
       ASSIGN,ATRIB(7)=EXPON(37); TIME TO ID ITEM
       COLCT,ATRIB(7),UNID,,;
       ACT,,,NEXT; GO TO NEXT LABEL
;====================================================
;         THIS SECTION COLLECTS COMBINED STATS AND COMPARES
;         COUNTERS AGAINST #ROOMS AND #ITEMS INVENTORIED SO
;         THAT THE PROGRAM CAN CYCLE THROUGH CONDITIONAL BRANCHING
;====================================================
NEXT   GOON;
       ASSIGN,XX(7)=XX(7)+1; INCREASE ROOM COUNTER
       ASSIGN,XX(8)=XX(8)+1; INCREASE ITEM COUNTER
       ACT,,XX(8).LT.ATRIB(3),G1;
       ACT,,XX(7).GE.XX(1).AND.XX(8).GE.ATRIB(3),DONE;
       ACT,,XX(8).GE.ATRIB(3).AND.XX(7).LT.XX(1),ROOM;
;====================================================
;         THIS MODULE TERMINATES THE SIMULATION PROGRAM
;====================================================
DONE   GOON;
       TERM;

       ENDNETWORK;
MONTR,CLEAR;
FIN;
```

Appendix D: Model II SLAM Coding

```
GEN, T.W. BECKWITH,INVENTORY METHODS,07/13/86,10;
LIMITS,1,6,150
INTLC,XX(1)=200;
SEED,9375295(1)/YES; TO SYNC RUNS
NETWORK;
;***********************************************
;          PROPERTY CUSTODIAN AND #ITEMS IN ROOM
;***********************************************
        CREATE,,,1; GENERATE PROPERTY CUSTODIAN
ROOM    GOON;
        ACT/1,; WALKING TIME BETWEEN ROOMS
        ASSIGN,ATRIB(2)=EXPON(9);
        COLCT,ATRIB(2),WALK;
        ASSIGN,II=10,ATRIB(3)=II;
        ACT/2,; ENTRY INTO READER
        ASSIGN,ATRIB(4)=EXPON(16);
        ASSIGN,XX(8)=1; COUNTER FOR ROOMS
        COLCT,ATRIB(4),ENTRY;
G1      GOON;
;***********************************************
;         PROBABILITY BRANCHING OF CATEGORIES OF ITEMS
;***********************************************
        ACT/3,,.05,UN; UNIDENTIFIED ITEM
        ACT/4,,.95,BC; BAR CODE ID PROG
;************************************************
BC      GOON; BAR CODE LABEL INVENTORY
        ASSIGN,ATRIB(5)=EXPON(4); INV TIME REQUIRED
        COLCT,ATRIB(5),BC,,;
        ACT,,,NEXT; GO TO NEXT LABEL
;************************************************
UN      GOON; UNIDENTIFIED ITEM INVENTORY
        ASSIGN,ATRI(6)=EXPON(38); TIME TO ID ITEM
        COLCT,ATRIB(6),UNID,,;
        ACT,,,NEXT; GO TO NEXT LABEL
;************************************************
;         THIS SECTION COLLECTS COMBINED STATS AND COMPARES
;         COUNTERS AGAINST #ROOMS AND #ITEMS INVENTORIED SO
;         THAT THE PROGRAM CAN CYCLE THROUGH CONDITIONAL BRANCHING
;************************************************
NEXT    GOON;
        ASSIGN,XX(7)=XX(7)+1; INCREASE ITEM COUNTER
        ASSIGN,XX(8)=XX(8)+1;
        ACT,,XX(8).LT.ATRIB(3),G1;
        ACT,,XX(7).GE.XX(1).AND.XX(8).GE.ATRIB(3),DONE;
        ACT,,XX(8).GE.ATRIB(3).AND.XX(7).LT.XX(1),ROOM;
;*************************************************
;         THIS MODULE TERMINATES THE SIMULATION PROGRAM
;*************************************************
DONE    GOON;
        TERM;
        ENDNETWORK;
MONTR,CLEAR;
FIN;
```

1-7

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.H. BECKWITH

DATE 7/ 3/1986   RUN NUMBER   1 OF   10

CURRENT TIME   0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.1023E+02	0.1062E+02	0.1038E+01	0.2247E+00	0.3242E+02	12
HSH	0.3722E+01	0.3040E+01	0.8167E+00	0.2351E+00	0.1407E+02	36
INDEX	0.9871E+01	0.8363E+01	0.8478E+00	0.3078E+00	0.3017E+02	16
ALL	0.1583E+02	0.1304E+02	0.8232E+00	0.5344E-01	0.4963E+02	48
UNID	0.4214E+02	0.5587E+02	0.1326E+01	0.1739E+0[illegible]	0.1656E+03	8

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

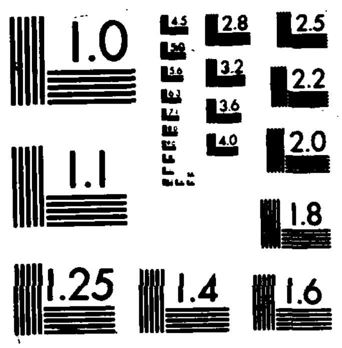
REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 SE PROB	NO VALUES RECORDED		1	0	8
3	NO VALUES RECORDED		1	0	36
4	NO VALUES RECORDED		1	0	16
5	NO VALUES RECORDED		1	0	48

EXECUTION WILL BE ATTEMPTED

AD-A174 651 USE OF BAR CODING IN THE PERFORMANCE OF PHYSICAL INVENTORIES ON UNITED ST (U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST T W BECKWITH 2/2

UNCLASSIFIED SEP 86 AFIT/GLM/LSM/86S-3 F/G 15/5 NL



CROCOPY RESOLUTION TEST CHART

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS BY T.W. BECKWITH

DATE 7/ 3/1986 RUN NUMBER 2 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEAREC AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.4715E+01	0.5018E+01	0.1064E+01	0.3604E-01	0.1382E+02	12
NSN	0.5439E+01	0.4833E+01	0.8887E+00	0.3962E-01	0.1983E+02	40
INDEX	0.1655E+02	0.2593E+02	0.1567E+01	0.3305E+00	0.1174E+03	19
ALL	0.1378E+02	0.1237E+02	0.8971E+00	0.7594E+00	0.4386E+02	41
UNID	0.4780E+02	0.5787E+02	0.1211E+01	0.4249E+01	0.1858E+03	8

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDEC		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	8
3	NO VALUES RECORDED		1	0	40
4	NO VALUES RECORDED		1	0	19
5	NO VALUES RECORDED		1	0	41

EXECUTION WILL BE ATTEMPTED

1-2

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 3 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEAREC AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.6828E+01	0.3823E+01	0.5599E+00	0.1682E+01	0.1417E+02	12
NSN	0.4698E+01	0.3813E+01	0.8116E+00	0.1152E+00	0.1566E+02	31
INDEX	0.1136E+02	0.3530E+01	0.8387E+00	0.6194E+00	0.3930E+02	24
ALL	0.1847E+02	0.2080E+02	0.1126E+01	0.1054E+00	0.9958E+02	43
UNID	0.4395E+02	0.3502E+02	0.7968E+00	0.9484E+00	0.1130E+03	10

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDEC		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	10
3	NO VALUES RECORDED		1	0	31
4	NO VALUES RECORDED		1	0	24
5	NO VALUES RECORDED		1	0	43

EXECUTION WILL BE ATTEMPTED

E. 3

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS — BY T.W. BECKWITH

DATE 7/ 3/1986 — RUN NUMBER 4 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.1030E+02	0.8067E+01	0.7831E+00	0.4152E+00	0.2599E+02	12
NSN	0.4799E+01	0.3814E+01	0.7947E+00	0.2876E-01	0.1439E+02	39
INDEX	0.1021E+02	0.7517E+01	0.7361E+00	0.7768E+00	0.2718E+02	20
ALL	0.1559E+02	0.1412E+02	0.9053E+00	0.3135E+00	0.6065E+02	45
UNID	0.5221E+02	0.4996E+02	0.9570E+00	0.1044E+02	0.1190E+03	4

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	4
3	NO VALUES RECORDED		1	0	39
4	NO VALUES RECORDED		1	0	20
5	NO VALUES RECORDED		1	0	45

EXECUTION WILL BE ATTEMPTED

E.4

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER   5 OF   10

CURRENT TIME   0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME   0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.8353E+01	0.7364E+01	0.8817E+00	0.4615E+00	0.2237E+02	12
NSN	0.4839E+01	0.3745E+01	0.7739E+00	0.5272E-01	0.1392E+02	40
INDEX	0.1376E+02	0.1242E+02	0.9023E+00	0.3617E+00	0.4359E+02	21
ALL	0.2404E+02	0.2219E+02	0.9229E+00	0.6216E+00	0.1137E+03	43
UNID	0.4145E+02	0.4445E+01	0.1073E+00	0.3755E+02	0.4586E+02	4

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	4
3	NO VALUES RECORDED		1	0	40
4	NO VALUES RECORDED		1	0	21
5	NO VALUES RECORDED		1	0	43

EXECUTION WILL BE ATTEMPTED

E 5

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS BY T.W. BECKWITH

DATE 7/ 3/1986 RUN NUMBER 6 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.9122E+01	0.7423E+01	0.8137E+00	0.3182E-02	0.2578E+02	12
NSN	0.5841E+01	0.7431E+01	0.1272E+01	0.1684E+00	0.2952E+02	39
INDEX	0.9236E+01	0.1054E+02	0.1141E+01	0.4008E+00	0.4312E+02	21
ALL	0.2018E+02	0.1653E+02	0.8192E+00	0.7779E+00	0.6670E+02	44
UNID	0.3645E+02	0.3399E+02	0.9325E+00	0.1673E+01	0.6810E+02	4

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	4
3	NO VALUES RECORDED		1	0	39
4	NO VALUES RECORDED		1	0	21
5	NO VALUES RECORDED		1	0	44

EXECUTION WILL BE ATTEMPTED

E. 6

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 7 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.9193E+01	0.6669E+01	0.7255E+00	0.4606E+00	0.2587E+02	12
NSN	0.5769E+01	0.4228E+01	0.7330E+00	0.4984E-01	0.1668E+02	41
INDEX	0.9086E+01	0.9281E+01	0.1022E+01	0.7029E+00	0.3786E+02	19
ALL	0.1767E+02	0.1785E+02	0.1010E+01	0.4580E+00	0.8456E+02	42
UNID	0.4883E+02	0.2564E+02	0.5252E+00	0.2509E+02	0.8325E+02	6

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	6
3	NO VALUES RECORDED		1	0	41
4	NO VALUES RECORDED		1	0	19
5	NO VALUES RECORDED		1	0	42

EXECUTION WILL BE ATTEMPTED

E. 7

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 8 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.7479E+01	0.5072E+01	0.6782E+00	0.1031E+01	0.1872E+02	12
NSN	0.4178E+01	0.3193E+01	0.7617E+00	0.1862E+00	0.1214E+02	44
INDEX	0.1087E+02	0.8901E+01	0.8188E+00	0.2706E+00	0.2652E+02	14
ALL	0.1510E+02	0.1485E+02	0.5834E+00	0.2596E+00	0.6508E+02	43
UNIO	0.2734E+02	0.2202E+02	0.8053E+00	0.1318E+00	0.5677E+02	7

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	7
3	NO VALUES RECORDED		1	0	44
4	NO VALUES RECORDED		1	0	14
5	NO VALUES RECORDED		1	0	43

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 9 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.8538E+01	0.8060E+01	0.9440E+00	0.1767E+00	0.2935E+02	12
NSN	0.6654E+01	0.4762E+01	0.7156E+00	0.8729E-01	0.2069E+02	45
INDEX	0.6979E+01	0.6879E+01	0.9857E+00	0.9720E-01	0.2015E+02	12
ALL	0.1541E+02	0.1620E+02	0.1052E+01	0.5797E+00	0.8528E+02	40
UNIO	0.1392E+02	0.1357E+02	0.9745E+00	0.1532E+01	0.4087E+02	11

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 5% PROB	NO VALUES RECORDED		1	0	11
3	NO VALUES RECORDED		1	0	45
4	NO VALUES RECORDED		1	0	12
5	NO VALUES RECORDED		1	0	40

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 10 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.3223E+01	0.4514E+01	0.1400E+01	0.3551E+00	0.1638E+02	12
ENTRY	0.1061E+02	0.6258E+01	0.5897E+00	0.2208E+01	0.2432E+02	12
BC	0.3691E+01	0.3522E+01	0.9541E+00	0.4152E-01	0.1771E+02	102
UNID	0.2295E+02	0.1864E+02	0.8122E+00	0.4978E+00	0.4641E+02	6

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	6
4 BAR CODE ID	NO VALUES RECORDED		1	0	102

Appendix F: Model II SLAM Printout

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 1 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.8650E+01	0.7956E+01	0.9198E+00	0.1555E+00	0.2533E+02	12
ENTRY	0.1393E+02	0.1236E+02	0.8875E+00	0.1056E+01	0.4486E+02	12
BC	0.3636E+01	0.3407E+01	0.9370E+00	0.1187E-01	0.1790E+02	100
UNID	0.4093E+02	0.2489E+02	0.6072E+00	0.1379E+02	0.8218E+02	8

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	8
4 BAR CODE ID	NO VALUES RECORDED		1	0	100

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS BY T.W. BECKWITH

DATE 7/ 3/1986 RUN NUMBER 2 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.9813E+01	0.1278E+02	0.1302E+01	0.1151E+00	0.4519E+02	12
ENTRY	0.2524E+02	0.5166E+02	0.2046E+01	0.6407E-01	0.1878E+03	12
BC	0.3541E+01	0.3328E+01	0.9399E+00	0.3170E-01	0.1586E+02	100
UNID	0.2367E+02	0.2179E+02	0.9208E+00	0.4933E+00	0.5983E+02	8

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	8
4 BAR CODE ID	NO VALUES RECORDED		1	0	100

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 3 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.9187E+01	0.6163E+01	0.6708E+00	0.1043E+01	0.2184E+02	12
ENTRY	0.1991E+02	0.2311E+02	0.1161E+01	0.3337E+01	0.8852E+02	12
BC	0.4297E+01	0.3473E+01	0.8082E+00	0.2343E-01	0.1572E+02	98
UNID	0.3584E+02	0.3573E+02	0.9972E+00	0.3604E+01	0.1190E+03	10

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	10
4 BAR CODE ID	NO VALUES RECORDED		1	0	98

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 4 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.1287E+02	0.8090E+01	0.6288E+00	0.2709E+01	0.3032E+02	12
ENTRY	0.2880E+02	0.2827E+02	0.9817E+00	0.2446E+01	0.1011E+03	12
BC	0.3965E+01	0.3801E+01	0.9586E+00	0.2300E-01	0.1857E+02	104
UNID	0.1345E+02	0.1580E+02	0.1174E+01	0.1225E+01	0.3631E+02	4

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	4
4 BAR CODE ID	NO VALUES RECORDED		1	0	104

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 5 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.1531E+02	0.1391E+02	0.9091E+00	0.3025E+01	0.5262E+02	12
ENTRY	0.2105E+02	0.2789E+02	0.1325E+01	0.2980E+00	0.9446E+02	12
BC	0.3841E+01	0.2845E+01	0.7407E+00	0.1381E+00	0.1146E+02	104
UNID	0.2175E+02	0.1726E+02	0.7937E+00	0.5665E+01	0.4612E+02	4

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	4
4 BAR CODE ID	NO VALUES RECORDED		1	0	104

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 6 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.8342E+01	0.7181E+01	0.8609E+00	0.7205E+00	0.2025E+02	12
ENTRY	0.2862E+02	0.2566E+02	0.8965E+00	0.2534E+01	0.6499E+02	12
BC	0.4137E+01	0.3445E+01	0.8327E+00	0.1414E-02	0.1725E+02	104
UNID	0.1323E+02	0.1568E+02	0.1185E+01	0.2887E+01	0.3638E+02	4

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANCARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	4
4 BAR CODE ID	NO VALUES RECORDED		1	0	104

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 7 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.6976E+01	0.6258E+01	0.8572E+00	0.7731E+00	0.2083E+02	12
ENTRY	0.1509E+02	0.2044E+02	0.1355E+01	0.5977E+00	0.7517E+02	12
BC	0.3868E+01	0.3331E+01	0.8612E+00	0.1425E-01	0.1514E+02	102
UNID	0.3398E+02	0.4281E+02	0.1260E+01	0.5208E+01	0.1180E+03	6

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	6
4 BAR CODE ID	NO VALUES RECORDED		1	0	102

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 1/ 3/1986   RUN NUMBER   8 OF   10

CURRENT TIME   0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.6524E+01	0.6392E+01	0.5798E+00	0.3733E+00	0.2243E+02	12
ENTRY	0.1698E+02	0.1112E+02	0.6552E+00	0.1145E+01	0.3801E+02	12
BC	0.3535E+01	0.3060E+01	0.8656E+00	0.3888E-01	0.1304E+02	101
UNID	0.4479E+02	0.1719E+02	0.3839E+00	0.1426E+02	0.7311E+02	7

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	7
4 BAR CODE ID	NO VALUES RECORDED		1	0	101

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 7/ 3/1986   RUN NUMBER 9 OF 10

CURRENT TIME 0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME 0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WALK	0.1007E+02	0.1109E+02	0.1101E+01	0.6266E+00	0.3725E+02	12
ENTRY	0.2041E+02	0.2215E+02	0.1085E+01	0.2793E+00	0.7581E+02	12
BC	0.3744E+01	0.3355E+01	0.8961E+00	0.1146E-01	0.1598E+02	97
UNID	0.3590E+02	0.3198E+02	0.8908E+00	0.2487E+01	0.1062E+03	11

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 ENTRY INTO R	NO VALUES RECORDED		1	0	12
3 UNIDENTIFIED	NO VALUES RECORDED		1	0	11
4 BAR CODE ID	NO VALUES RECORDED		1	0	97

EXECUTION WILL BE ATTEMPTED

S L A M   I I   S U M M A R Y   R E P O R T

SIMULATION PROJECT INVENTORY METHODS   BY T.W. BECKWITH

DATE 1/ 3/1986   RUN NUMBER   10 OF   10

CURRENT TIME   0.0000E+00
STATISTICAL ARRAYS CLEARED AT TIME   0.0000E+00

STATISTICS FOR VARIABLES BASED ON OBSERVATION

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBSERVATIONS
WAIT	0.9693E+01	0.6865E+01	0.7082E+00	0.3942E+00	0.2388E+02	12
NSN	0.3805E+01	0.3510E+01	0.9223E+00	0.6155E-01	0.1397E+02	38
INDEX	0.1201E+02	0.9239E+01	0.7691E+00	0.9646E+00	0.2994E+02	13
ALL	0.1570E+02	0.1363E+02	0.8682E+00	0.5158E-01	0.7029E+02	51
UNID	0.3919E+02	0.5374E+02	0.1371E+01	0.5062E+01	0.1478E+03	6

FILE STATISTICS

FILE NUMBER	ASSOC NODE LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAITING TIME
1		NO VALUES RECORDED		0	0	
2	CALENDAR	NO VALUES RECORDED		1	0	

REGULAR ACTIVITY STATISTICS

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1 WALKING TIME	NO VALUES RECORDED		1	0	12
2 SE PROB	NO VALUES RECORDED		1	0	6
3	NO VALUES RECORDED		1	0	38
4	NO VALUES RECORDED		1	0	13
5	NO VALUES RECORDED		1	0	51

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Vita

Captain Terence W. Beckwith was born 25 December 1951 in Cleveland, Ohio. He graduated from Euclid Senior High School, Euclid Ohio in 1970. On 7 March 1971 he enlisted in the United States Air Force. He worked as a Medical Material Specialist for seven years and graduated from Troy State University in November 1976 receiving the degree of Bachelor of Applied Science, with a major in Resources Management. Captain Beckwith was commissiond on 13 April 1978 in the United States Air Force Medical Service Corps.

He has been awarded two Air Force Commendation medals and the Air Force Meritorious Service Medal. His assignments include being the Assistant Administrator, Medical Material USAF Hospital Little Rock AFB Arkansas; the Director, Medical Logistics Management and Director of Personnel and Administrative Services Hahn AB, Germany; the Medical Equipment Management Officer and the Assistant Director of Patient Affairs Wright-Patterson AFB Medical Center Ohio. Captain Beckwith completed Squadron Officers School in residence July 1984 and Air Command and Staff by correspondence May 1985. Captain Beckwith entered the School of Systems and Logistics at the Air Force Institute of Technology in May 1985.

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16. SUPPLEMENTARY NOTATION

17. COSATI CODES

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15	5	
6	12	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Bar Codes, Inventory, Inventory Control
Accountability, Automatic Tracking

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Title: USE OF BAR CODING IN THE PERFORMANCE OF PHYSICAL INVENTORIES ON UNITED STATES AIR FORCE MEDICAL EQUIPMENT MANAGEMENT OFFICE (MEMO) CONTROLLED PROPERTY

Thesis Chairman: Bruce P. Christensen, Lt Col, USAF
Assistant Professor of Logistics Management

Approved for public release: IAW AFR 190-1/.
LYNN E. WOLAVER 29 Sept 86
Dean for Research and Professional Development
Air Force Institute of Technology ~~(ATC)~~
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This research examined the times and techniques necessary for individuals responsible for property accountability within USAF medical facilities to conduct physical inventories on medical and nonmedical equipment. Because this property accountablility normally is an additional duty and their primary mission is that of patient care, the amount of time required to conduct these inventories should not be excessive. This is especially true when there are more advanced tecnhiques available that would improve the efficiency and decrease the time required to conduct these inventories. The examination included a review of how the present physical inventories are being accomplished and the advanced techniques available that would expedite this process. Trial physical intentories were performed on two accounts using both the present physical inventory method and the technique of bar coding. In addition, a simulation model for each method was developed using the results from the trial inventories. The results of the trial inventories and the output from the simulation models were anlayzed and compared. The conclusions reached as a result of the comparison are that the present method of conducting physical inventories is inefficient and the use of bar coding would dramatically decrease physical inventory times and improve efficiency.

END

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